EE2703 End semester Examination

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Abstract

The goal of this assignment is:

- To find magnetic field in z direction due to the circular loop antenna on x-y plane.
- Plot magnetic field Vs Z to understand it better in loglog scale.
- To find the best fit values if b,c using

$$|B| = cz^b$$

Pseudocode

- Create a 3 by 3 by 1000 mesh in the space.
- Divide the loop into 100 parts.
- Obtain radius vector rl for each l as an array.
- Define a function(i.e calc(l)) that returns the norm and Axl,Ayl.
- Compute Rijkl-distance of each and every space point from lth current element. After this operation using vectorization ,we will have an array which contains the distances of each and every space point from lth current element .
- Perform vectorized operation and find Aijklx and Aijkly using equation given in question.
- Calc(l) have values of Axl,Ayl,Rijkl. Use for loop for 100 iterations so that we will get Ax,Ay at a point due to each current element.
- Find Bz using vectorized operations.
- Plot Bz Vs Z in loglog scale
- Use least squares approach to find the best fit.

Breaking the volume

we will break the space into 3 by 3 by 1000 mesh using meshgrid. First we will define x,y,z such that each x is separated by 1cm. similarly for y and z also. The meshgrid outputs are stored in rijk array. The following python code snippet is used for this:

```
x=linspace(-1,1,3)
y=linspace(-1,1,3)
z=arange(1,1001,1)
X,Y,Z=meshgrid(x,y,z)
rijk =zeros((3,3,1000,3))
rijk[:,:,:,0]=X
rijk[:,:,:,1]=Y
rijk[:,:,:,2]=Z
```

Breaking the loop and plotting current elements

Here we should break the loop into 100 parts and then we should plot the current elements as dots at midpoint of each current element. In addition to that we will also plot current direction in each current element using a quiver function. The following python code snippet is used to do this:

```
phi_l=linspace(0,2*pi,101)
phi_l=phi_l[:-1]
I=zeros((2,N))
r=zeros((2,N))
I[0]=-1e7*((cos(phi_l)))*(sin(phi_l))
I[1]=1e7*((cos(phi_l)))*(cos(phi_l))
r[0]=a*(cos(phi_l))
r[1]=a*(sin(phi_l))
rxy = zeros((2,N))
rxy[0] = a*(cos((phi_l)+(pi/N)))
rxy[1] = a*(sin((phi_l)+(pi/N)))

# plotting current elements in x-y plane
figure(0)
plot(rxy[0],rxy[1],'ro')
xlabel('X $\longrightarrow$ ',size=10)
ylabel('Y $\longrightarrow$ ',size=10)
title('plot of current elements in x-y plane')
axis('square')
grid('True')
```

The plot to the above code is shown below:

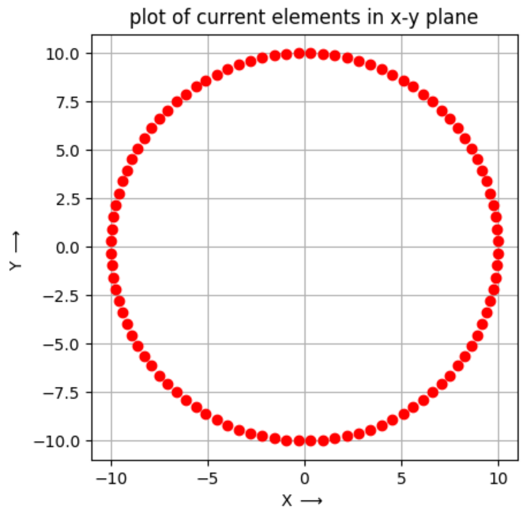

Figure 1: Current elements in x-y plane

```
# plotting current using quiver
figure(1)
quiver(r[0],r[1],I[0],I[1],scale=1e8)
axis('square')
xlabel('X $\longrightarrow$ ',size=10)
axis('square')
ylabel('Y $\longrightarrow$ ',size=10)
title('Current Flow in The Loop using quiver',size=12)
grid('True')
```

The plot to the above code is shown below:

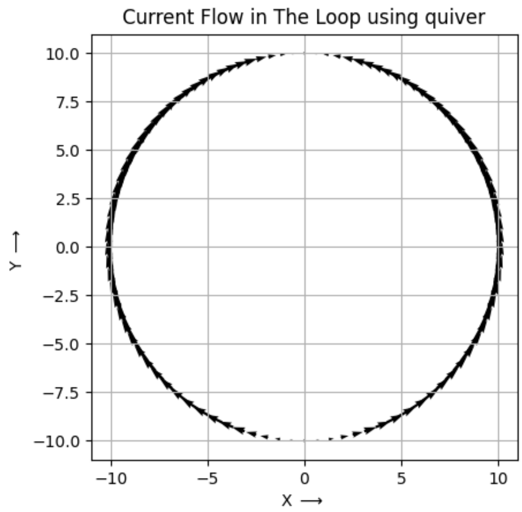

Figure 2: Quiver plot of current in the current elements

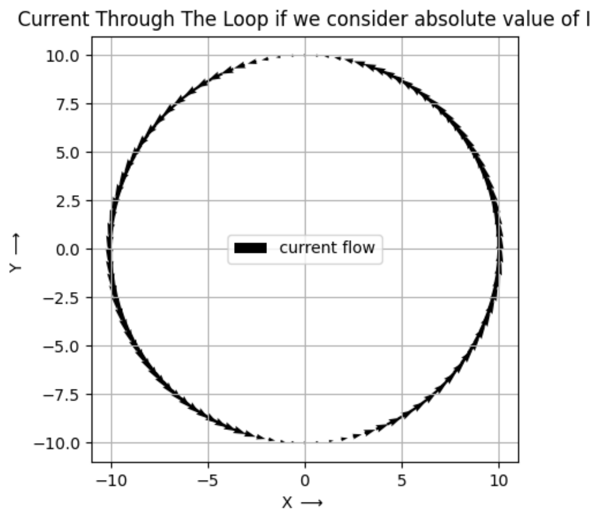

Figure 3: Current through loop if we consider absolute value of I

rl and dl vectors

In this section we will get rl and dl vectors for each current element.The below python code is used for this:

```
dl = zeros((2,N))
r_l=c_[a*(cos(phi_l)),a*(sin(phi_l)),zeros(N)]
dl[0] = -(2*pi*a/N)*sin(phi_l)
```

```
dl[1] = (2*pi*a/N)*cos(phi_l)
```

Defining calc(l) and extending it to find A

Here we define a function that calculates

$$R_{ijkl} = |r_{ijk} - r'_l|$$

for all rijk. The defined function will be in vectorized form since the variables used are vectors. And then we extend the function to return the variables that are required to add to vector potential. The mathematical equations for the variables are:

$$A_{xl} = ((cos(phi[l]))exp((-1j)k(Rijkl))(dl[0][l]))/Rijkl$$

$$A_{yl} = ((cos(phi[l]))exp((-1j)k(Rijkl))(dl[1][l]))/Rijkl$$

So the function returns R$_{ijkl}$, A_{xl}, Ayl

The python code snippet used for this is shown below

```
def calc(l):
   def calc(l):
    Rijkl=linalg.norm(rijk-r_l[l],axis=-1)
    Axl=(abs((cos(phi_l[l])))*exp((-1j)*k*(Rijkl))*(dl[0][l]))/Rijkl
    Ayl=(abs((cos(phi_l[l])))*exp((-1j)*k*(Rijkl))*((dl[1][l])))/Rijkl
    return Rijkl,Axl,Ayl
```

Computing Aijk

Here we will use calc(l) function to compute Aijk using for loop which runs 1000 times. The python code snippet used for this is shown below.

```
Axl=Ayl=0
for i in range(N):
    R,dxl,dyl=calc(i)
    Axl+=dxl
    Ayl+=dyl
```

Finding magnetic field

We will find Bz using the formula given in question

$$B_z(z) = (Ay(\delta x, 0, z) + Ax(0, \delta y, z) - Ay(-\delta x, 0, z) + Ax(0, \delta y, z))/4\delta x\delta y$$

This equation is implemented using a simple vectorized python python code.

```
Bz=(Ayl[1,2,:]-Ayl[1,0,:]-(Axl[2,1,:]-Axl[0,1,:]))/4
```

Plotting the magnetic field Vs z plot

Now we will plot the magnetic field that we got above in loglog scale vs Z(in cm). We can do this using the simple python code shown below

```
figure(2)
loglog(z,abs(Bz),'b')
xlabel('z(cm) $\longrightarrow$ ',size=10)
ylabel('Bz $\longrightarrow$ ',size=10)
title('Magnetic Field Vs z')
grid('True')
```

The plot obtained from above code is shown below

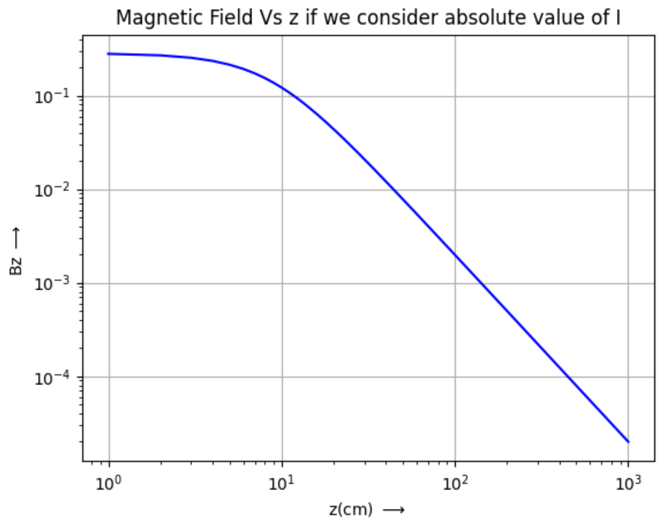

Figure 4: Plot of magnetic field versus Z if we consider only absolute value

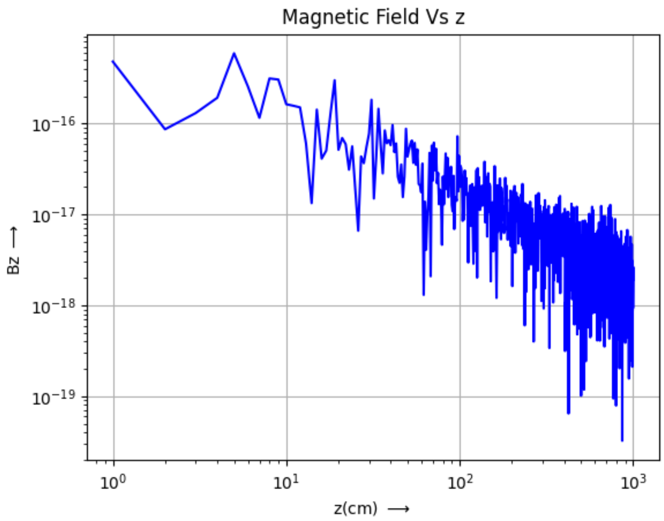

Figure 5: Plot of magnetic field Vs Z if we consider the given equation

Finding the best fit values

Here we fit the obtained data of magnetic field data to

$$|B| = cz^b$$

using a function in which we will find and print the values of c and b. We will execute this using the python snippet shown below

```
def lstsqfit(data):
    #input arguments:- data
    M=c_[ones(len(data)),log(arange(1001-len(data),1001,1))]
    est=linalg.lstsq(M,log(data),rcond=None)[0]
    return exp(est[0]),est[1]
c,b = lstsqfit(abs(Bz))
print('best fit value of c is :',c)
print('best fit value of b is :',b)
```

The obtained values of c and b if we take current as mentioned in the question are:
c=1.3e-15 and b=-0.961
The obtained values of c and b if we take absolute value of current are:
c=11.213 and b=-1.905

Conclusion

As per the current expression given in the question,since the loop and magnetic field due to the current elements are symmetric about z-axis,the magnetic field on z-axis cancels out and results in zero.But here we get very small values of field due to the approximation we took that the magnetic vector potential as summation instead of integration.

If we consider the absolute value of current,the magnetic field due to symmetrical elements adds up instead of cancelling out,which therefore results in a non zero magnetic field along the z-axis.The pots for Bz in both cases is shown above.The decay constant obtained here is -1.9(approximately -2)

Where as in the static case,since the current is a constant,the magnetic field varies with a decay constant of -3.The reason for the difference in the decay constant is that in case of magnetostatics,we won't consider the exponential term in the current,and when we fit the data in the same way as above,we obtain a decay constant of -2.8(approximately equal to -3).