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PHY 6860

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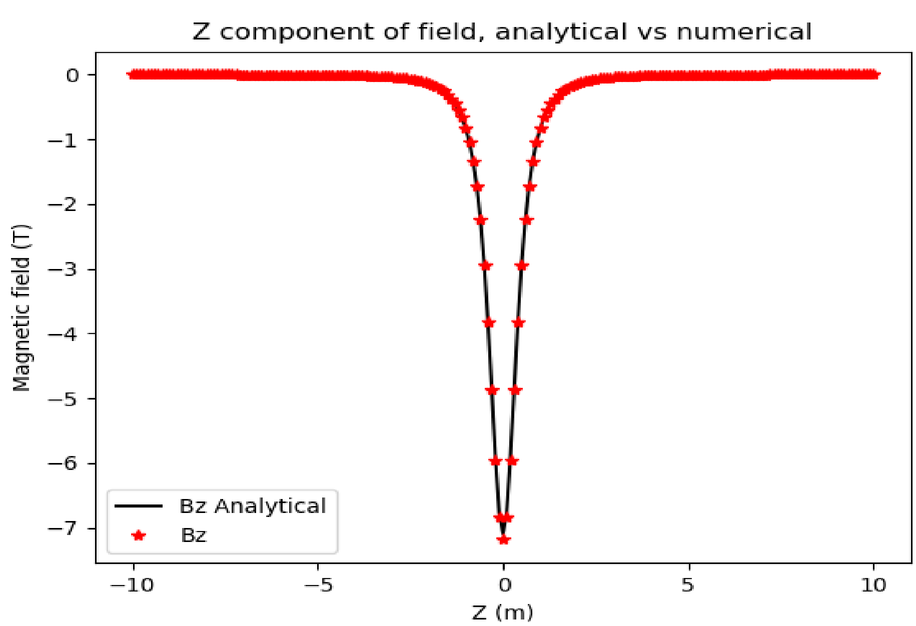
Midterm Problem 2

For this problem, I had to measure components of a magnetic field coming from a square wire of current. I measured each component for specific points on the (x, y, z) coordinate grid and compared the values for different points. I used conditions x=y=0 to compare components for z values, y=0 z=1 for x values, and x=0.5 y=0 again for z values.

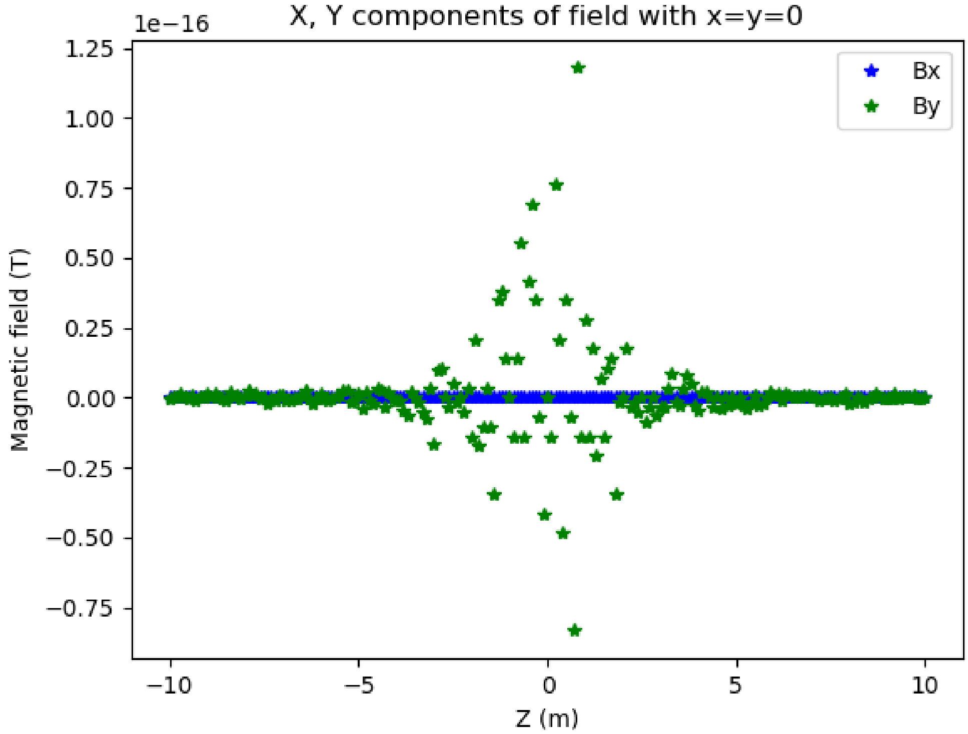
For the first condition, I calculated components analytically for comparison sake. I assumed the square loop to be like a circular loop with the same area of 1 m^2. Analytically for the given conditions, the x and y components are 0, and the z component is measured by the equation: $\frac{\mu_0 I r^2}{2(z^2+r^2)^{1.5}}$

$\mu_0 I$ was given, and r can be found from our given area. I then plotted the z component with respect to z. Afterwards, I calculated the components numerically with this process:

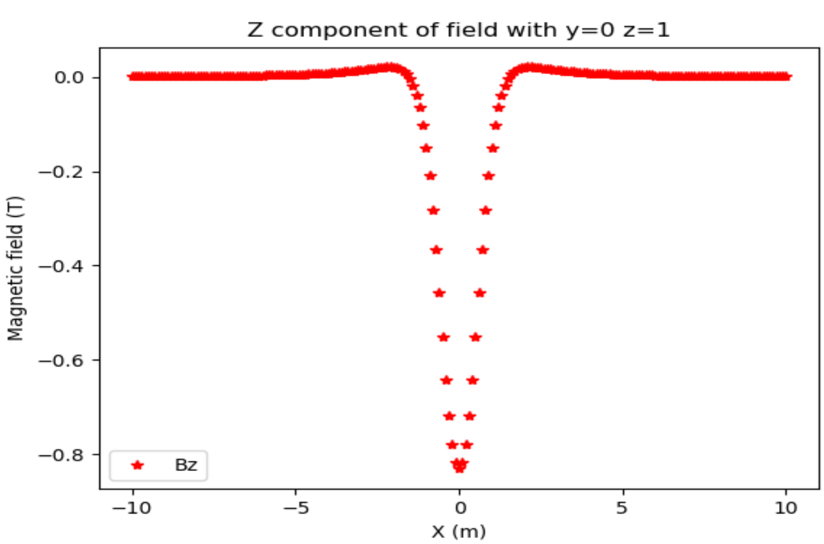
- Made for loop to calculate components at different z values
    - Re-initialized changes of the field components for each iteration
- Made for loops for each z iteration to add up the components for the (x, z) coordinate grid
    - Limits are the square wire because no field is added outside of those limits
    - Defined vectors R-prime (for x,y grid), R (perpendicular, and L (R-R-prime)
        - Defined DR-Prime (change R-Prime)
    - These vectors used to adjust the magnetic field components for a single iteration
    - Components only adjusted for iterations on the current loop
        - Each quadrant of the current loop changed field components differently due to different DR-Prime values, based on direction of movement along the loop
    - Changes from all 4 quadrants added up for each z value
- Total field for each z value plotted vs z values
    - On same graph as analytical solution



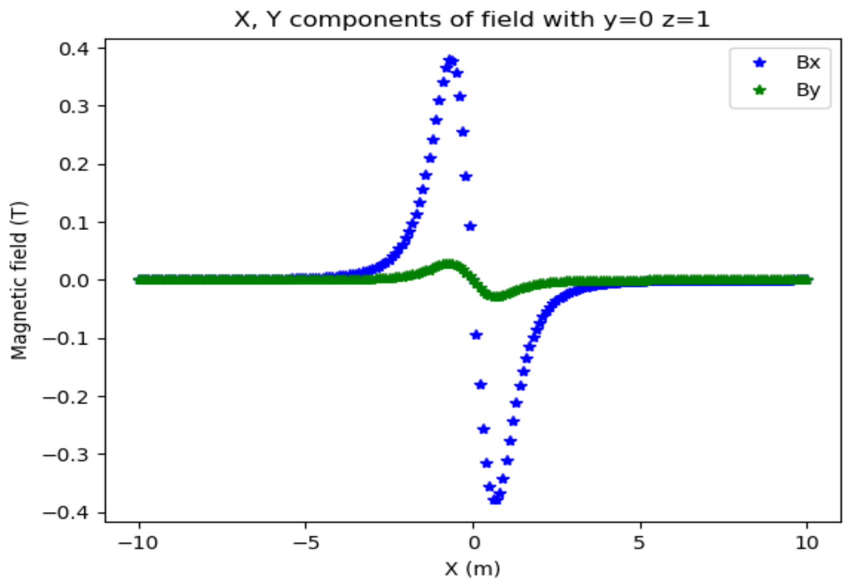
- The model was quite accurate, as the two plots are nearly identical
    - Fields are negative due to the counter-clockwise motion along the loop, otherwise plots would be flipped over the x axis
- We also plotted the x and y components for each z value



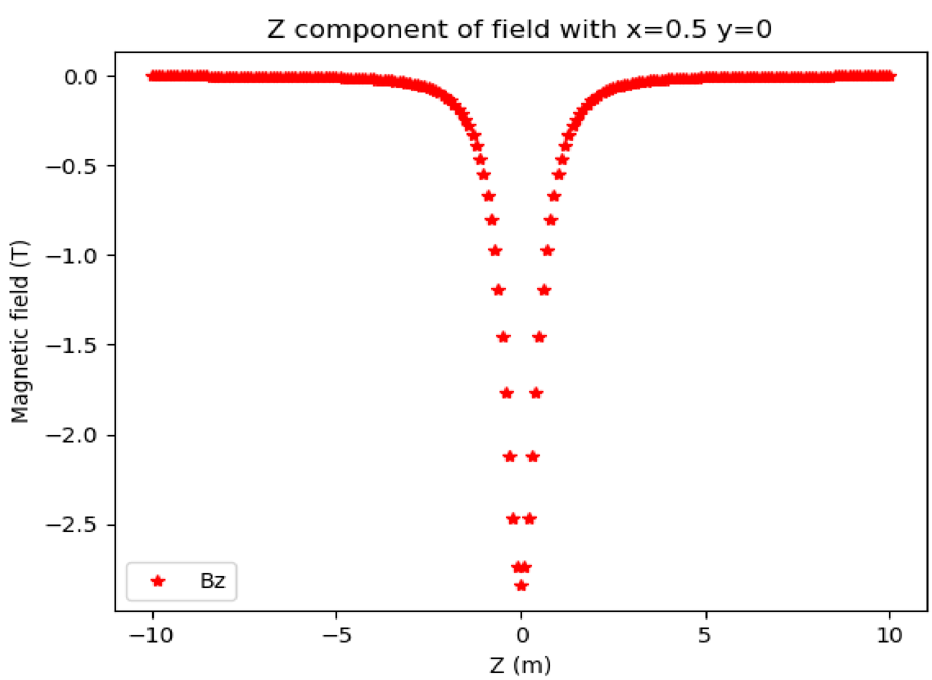
- The graph shows extremely small magnetic fields for these two components, which is due to error of the numerical method
    - Analytically, these components should equal 0 for all Z
- Next, we repeated the first numerical model, but we calculated components for x values
    - Z was constant at 1, along with y constant at 0
- Made for loop for x values
    - Made nested for loops for each x value to add up components for the (x, y) grid
        - Used same 4-quadrant system
- Plotted z components for different x values



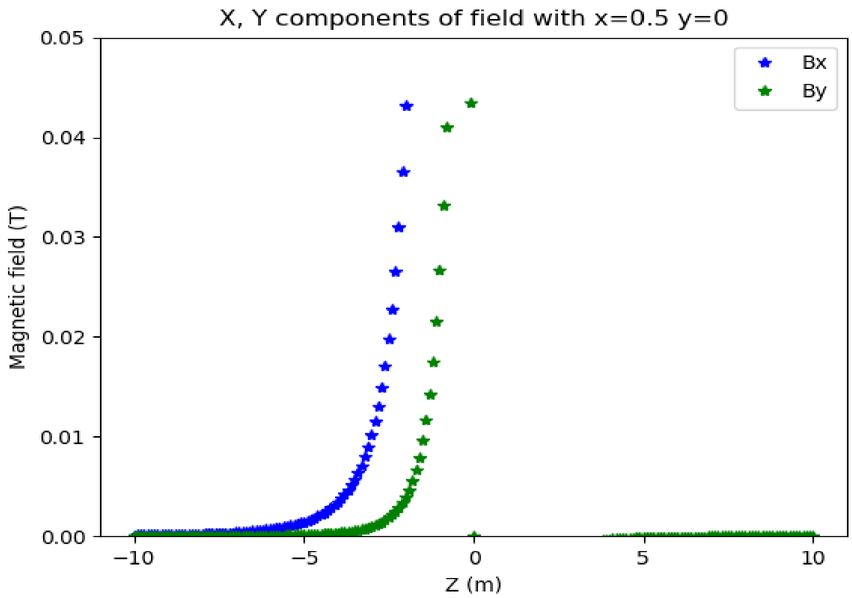
- Shows a similar trend with varying x values as varying z values, but the field magnitudes are significantly lower, likely because z=1 which is quite far from the loop
- Plotted x and y components



- Since the x and y coordinates are no longer both constant at 0, these components are nonzero
  - The magnitudes may be small, but they are noticeably increasing in absolute value with x values close to the loop
- We repeated the first numerical model again, also with variation of z values, but with a small adjustment of x=0.5 instead of 0
  - Now, the x values are on, directly above, or directly below the loop
- Same iteration process over the (x, y) grid
- Plotted z component vs z values



- Similar to the model where x=y=0, but with smaller magnitudes of the field component
    - This decrease is likely due to the change in x value
- Plotted the x and y components



- Again, these components are nonzero because X is nonzero
    - A few outliers are not included to make the graph trend more visual
    - Like all the other plots, components closer to the loop are exponentially higher in absolute value

From this problem, I could visualize the accuracy of the numerical method for x=y=0. I got the sense that for different initial conditions, the method was just as accurate, based on the shapes of my plots. I saw that the nonzero x and y components had clear trends, which makes me believe they were accurate.