Lab Assignment

Utkarsh Jaiswal

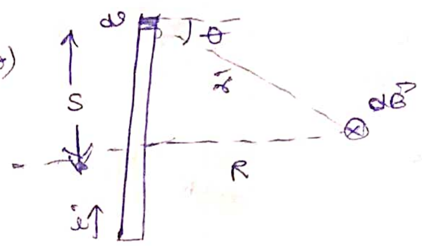
18EX20030

Derivation of horizontal and vertical component of secondary magnetic field due to infinite current carrying cable

Magnetic flux density, B.

$$\vec{dB} = \frac{\mu_0}{4\pi} \frac{i\vec{ds} \times \vec{r}}{r^3}$$

$$\vec{dB} = \frac{\mu_0}{4\pi} \frac{i\,ds\,(r\sin\theta)}{r^3}$$



$$\Rightarrow dB = \frac{\mu_0}{4\pi} \frac{i\,ds\,\sin\theta}{r^2}.$$

For infinite current carrying conductor, B will be derived by integrating both sides

$$\int_{-\infty}^{\infty} dB = \frac{\mu_0 i}{4\pi} \int_{-\infty}^{\infty} \frac{(ds)\sin\theta}{r^2}.$$

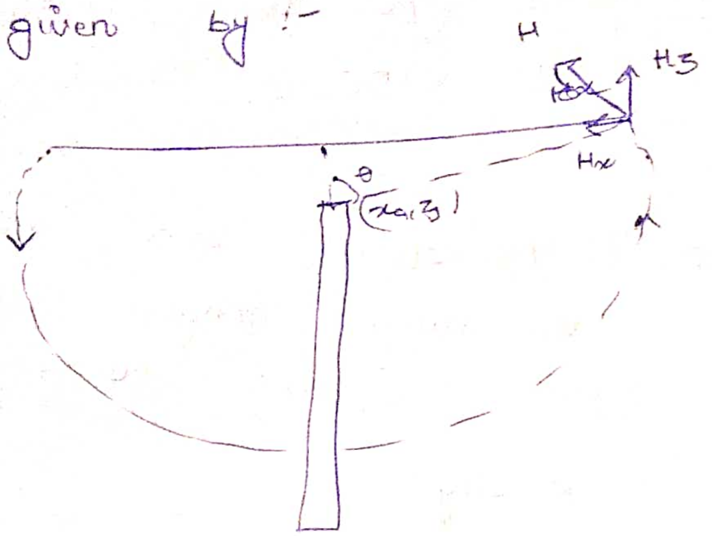
substitute value of $\sin\theta = \frac{R}{r}$, where $r = \sqrt{s^2+R^2}$

$$B = \frac{\mu_0 i}{4\pi} \int_{-\infty}^{\infty} \frac{R\,ds}{(s^2+R^2)^{3/2}}$$

$$= \frac{\mu_0 i R}{2\pi} \left[\frac{s}{R^2(s^2+R^2)^{1/2}} \right]_0^{\infty}$$

$$\therefore \boxed{B = \frac{\mu_0 I}{2\pi R}} \Rightarrow \boxed{H = \frac{B}{\mu_0} = \frac{I}{2\pi R}}$$

Vertical and Horizontal component of H is given by :-



$H_x = -H\cos\theta\,\hat{i}$

$\Rightarrow \quad H_x = -\dfrac{Hz}{R}$

$\Rightarrow \quad H_x = -\dfrac{I}{2\pi R}\left(\dfrac{z}{R}\right)$

$\Rightarrow \quad \boxed{H_x = -\dfrac{Iz}{2\pi R^2}}$ = Horizontal component of Magnetic Field

$H_z = H\sin\theta\,\hat{j}$

$= \dfrac{H(x_i - x_0)}{R}$

$\boxed{H_z = \dfrac{I(x_i - x_0)}{2\pi R^2}}$ Vertical component of Magnetic Field

From the graph we interpret :-

- As 'I' is in the numerator of the expressions of H_x and H_z so H_x and H_z is directly proportional to "I"

- Variation of H_x and H_z with depth.

$$H_x = \frac{-I}{2\pi R^2} \quad \text{where } R = \sqrt{(x_i - x_0)^2 + z^2}$$

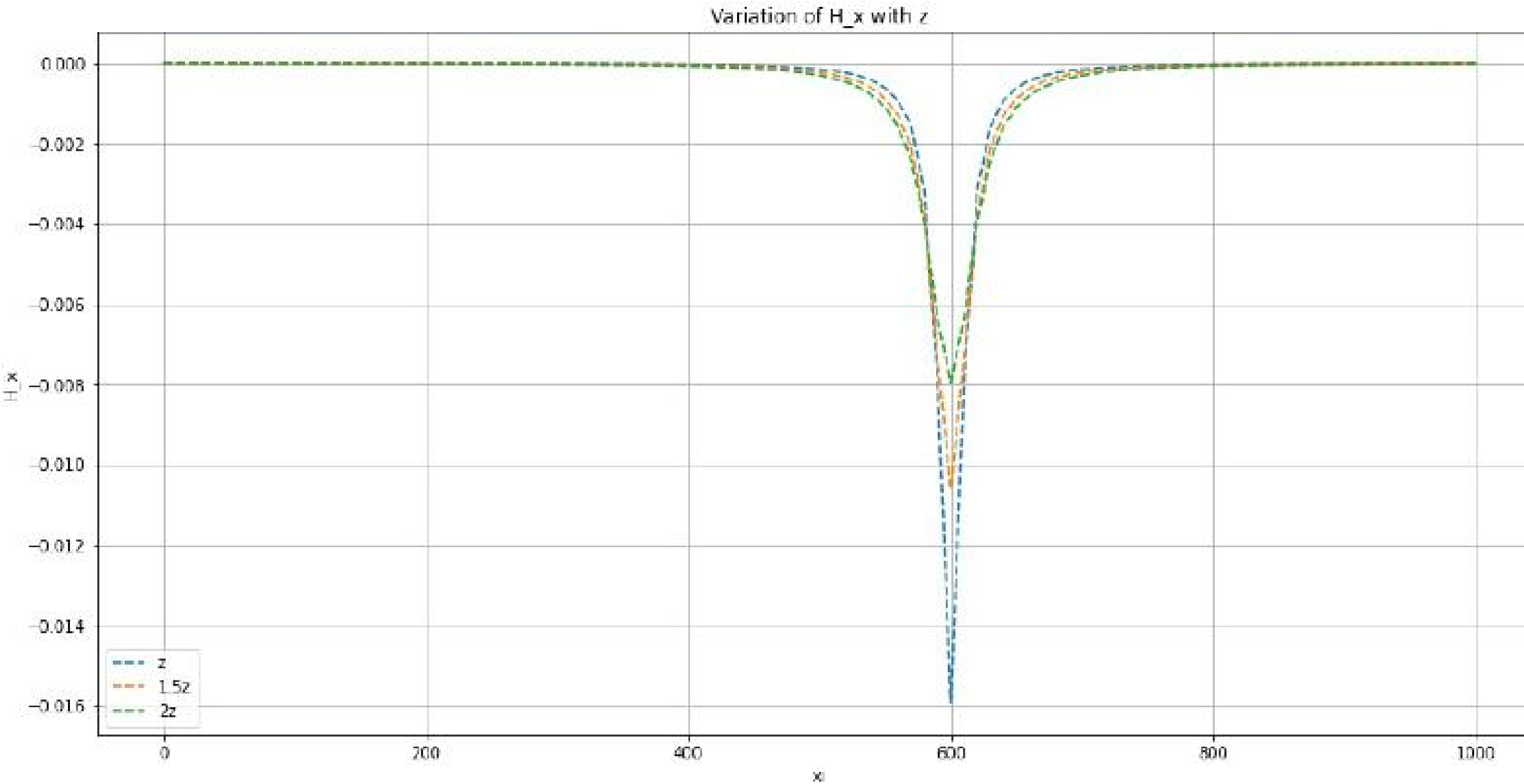
$$H_z = \frac{I(x_i - x_0)}{2\pi R^2}$$

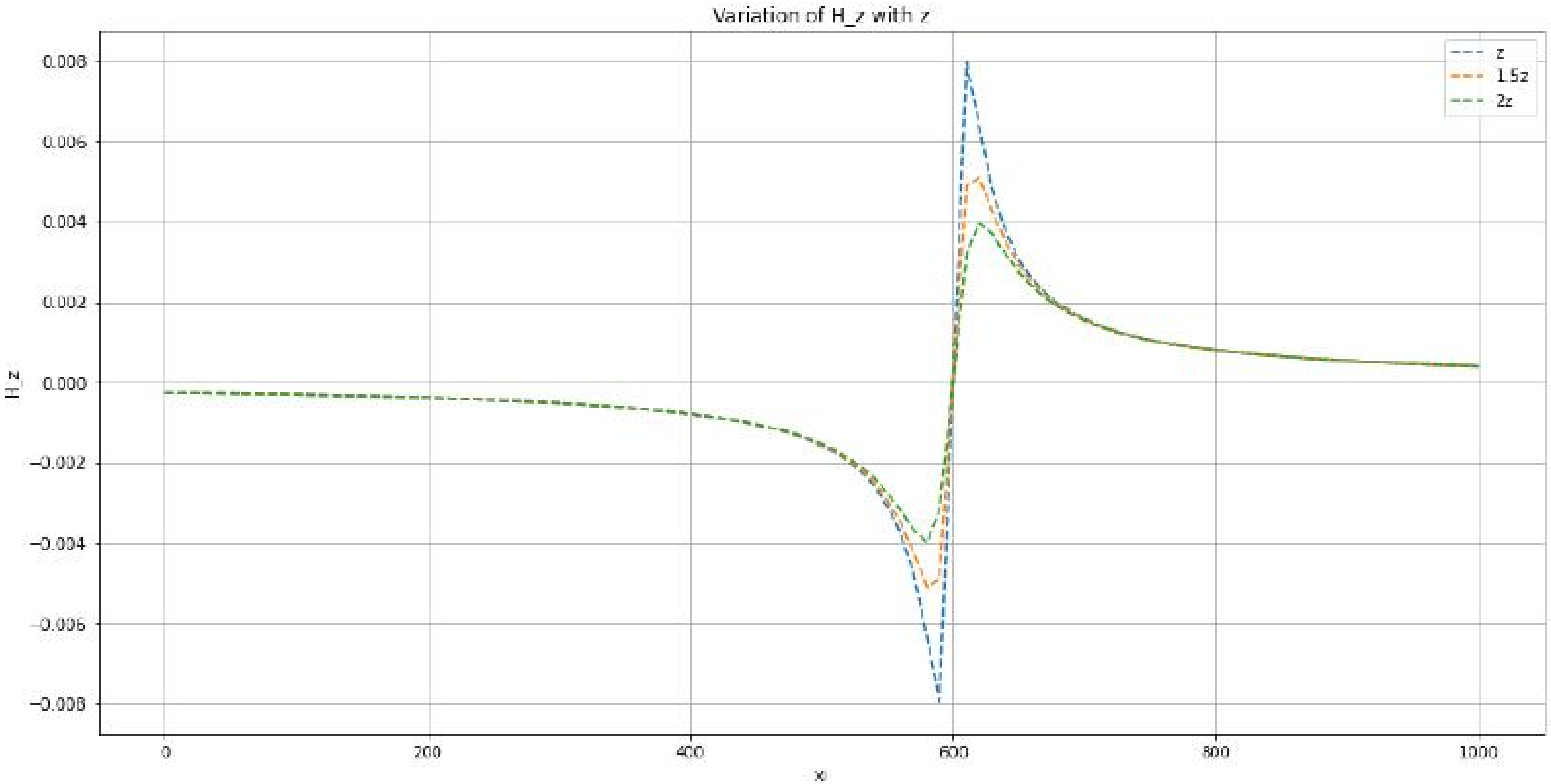
Due to increase in 'z' it will lead to decrease in overall H_z and H_x terms.

- Variation of H_x and H_z with x_0 (coordinate of the conductor).
From expression of H_x and H_z will simply result with change in x_0 in lateral shift.

```python
import matplotlib.pyplot as plt
import numpy as np

x0=600
z=10
I=1
xi=np.arange(0,1001,10)

def Mag_field(x0, z, I):
  R= np.sqrt((xi-x0)**2+z**2)
  H_x =-I*z/(2*np.pi*R*R)
  H_z =(I*(xi-x0)/(2*np.pi*R*R))
  return H_x,H_z


def plot(xi, H_x,H_z,H_x_1,H_z_1,H_x_2,H_z_2,title1, title2, label1,
label2, label3):
  plt.plot(xi, H_x,'--', label=label1)
  plt.plot(xi, H_x_1,'--',label=label2)
  plt.plot(xi, H_x_2,'--',label=label3)
  plt.title(title1)
  plt.xlabel('xi')
  plt.ylabel('H_x')
  fig = plt.gcf()
  fig.set_size_inches(16, 8)
  plt.legend()
  plt.grid()
  plt.show()
```

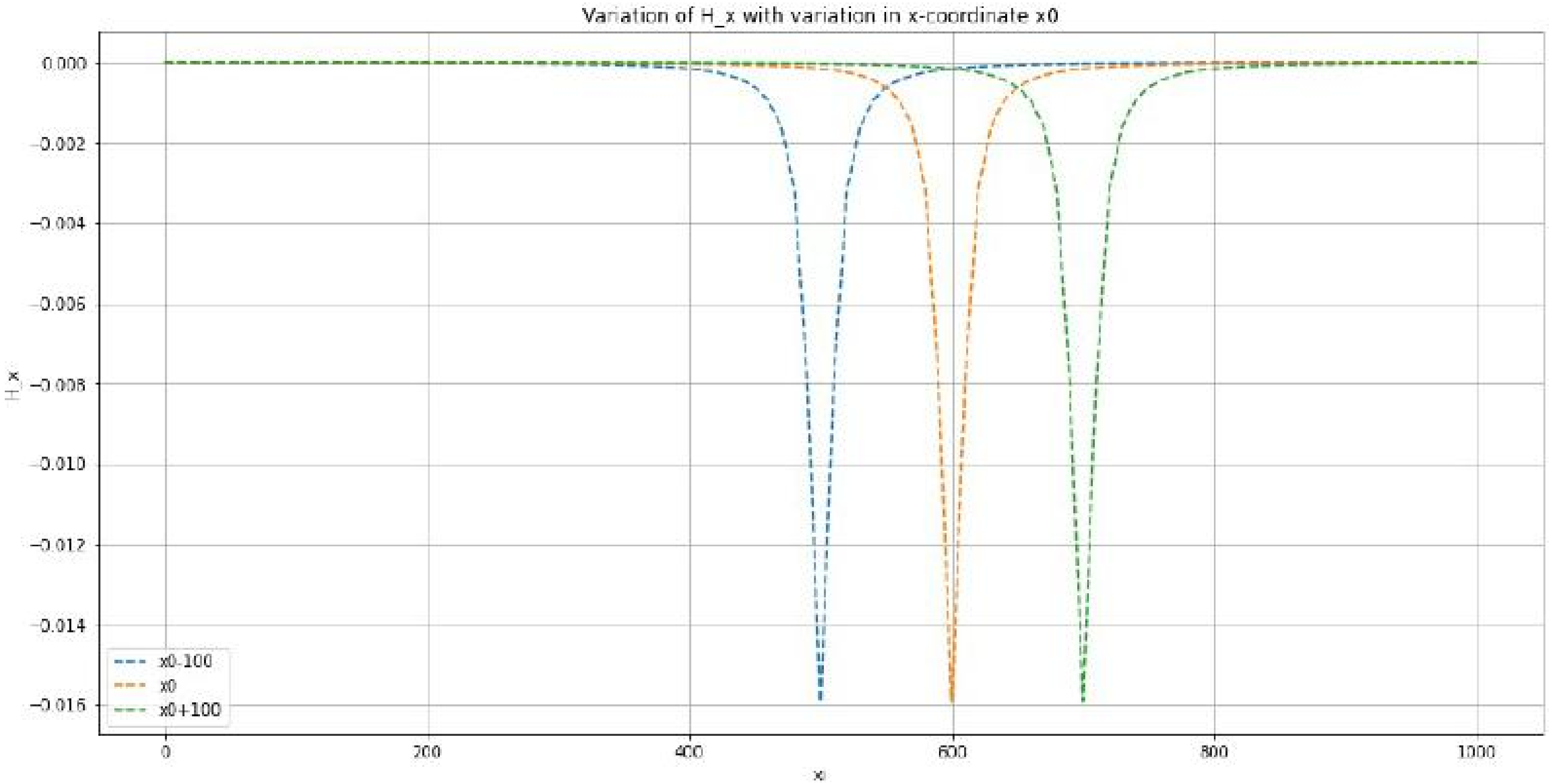
```
H_x,H_z= Mag_field(x0,z,I)
H_x_1, H_z_1=Mag_field(x0,1.5*z,I)
H_x_2, H_z_2=Mag_field(x0,2*z,I)
plot(xi, H_x,H_z,H_x_1,H_z_1,H_x_2,H_z_2,'Variation of H_x with z',
'Variation of H_z with z','z','1.5z','2z')
```

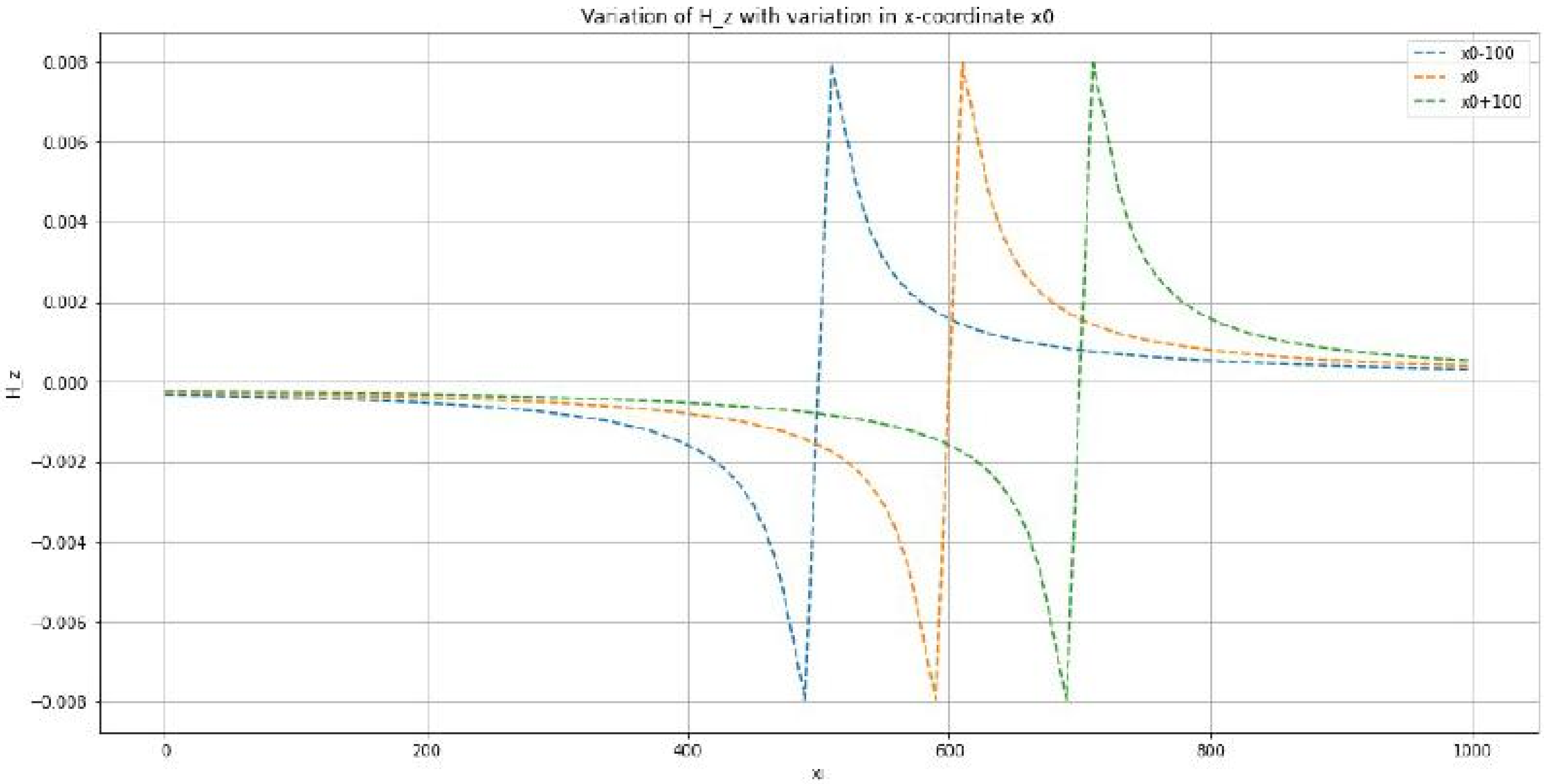

Variation of H_x with z
0.000
−0.002
−0.004
−0.006
−0.008
−0.010
−0.012
−0.014
−0.016
H_x
0
200
400
600
800
1000
x
z
1.5z
2z



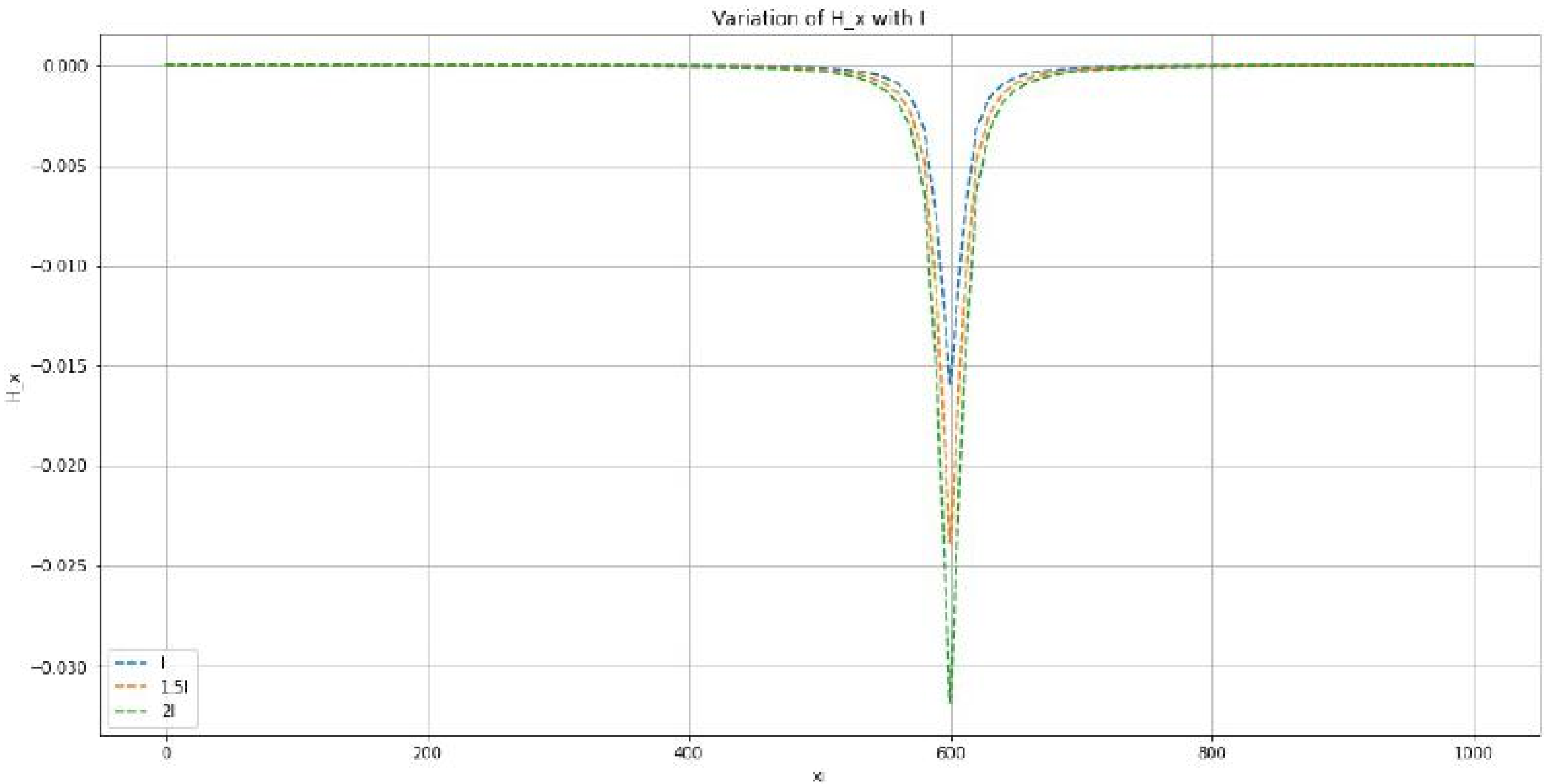
Variation of H_z with z
z
1.5z
2z
H_z
x
0.008
0.006
0.004
0.002
0.000
−0.002
−0.004
−0.006
−0.008
0
200
400
600
800
1000

```
H_x,H_z= Mag_field(x0-100,z,I)
H_x_1, H_z_1=Mag_field(x0,z,I)
H_x_2, H_z_2=Mag_field(x0+100,z,I)
plot(xi, H_x,H_z,H_x_1,H_z_1,H_x_2,H_z_2,'Variation of H_x with
variation in x-coordinate x0','Variation of H_z with variation in x-
coordinate x0','x0-100','x0','x0+100')
```

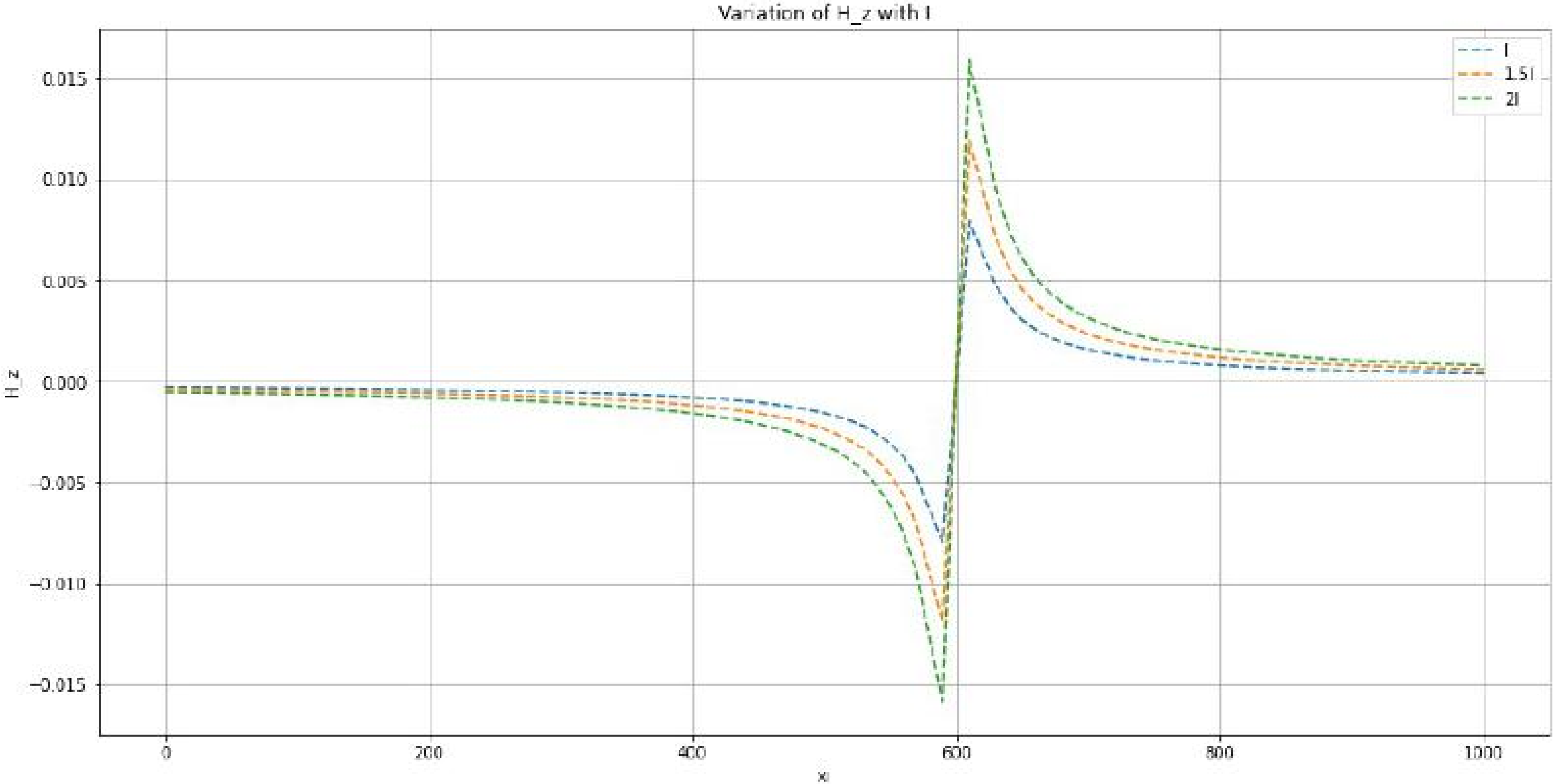

Variation of H_x with variation in x-coordinate x0
H_x
x
0.000
−0.002
−0.004
−0.006
−0.008
−0.010
−0.012
−0.014
−0.016
0
200
400
600
800
1000
x0-100
x0
x0+100


Variation of H_z with variation in x-coordinate x0
x0-100
x0
x0+100
H_z
x
0.008
0.006
0.004
0.002
0.000
−0.002
−0.004
−0.006
−0.008
0
200
400
600
800
1000

```
H_x,H_z= Mag_field(x0,z,I)
H_x_1, H_z_1=Mag_field(x0,z,1.5*I)
H_x_2, H_z_2=Mag_field(x0,z,2*I)
plot(xi, H_x,H_z,H_x_1,H_z_1,H_x_2,H_z_2,'Variation of H_x with I',
'Variation of H_z with I', 'I','1.5I', '2I')
```



Variation of H_x with I
0.000
−0.005
−0.010
−0.015
−0.020
−0.025
−0.030
H_x
0
200
400
600
800
1000
x
I
1.5I
2I


Variation of H_z with I
I
1.5I
2I
H_z
x
0.015
0.010
0.005
0.000
−0.005
−0.010
−0.015
0
200
400
600
800
1000