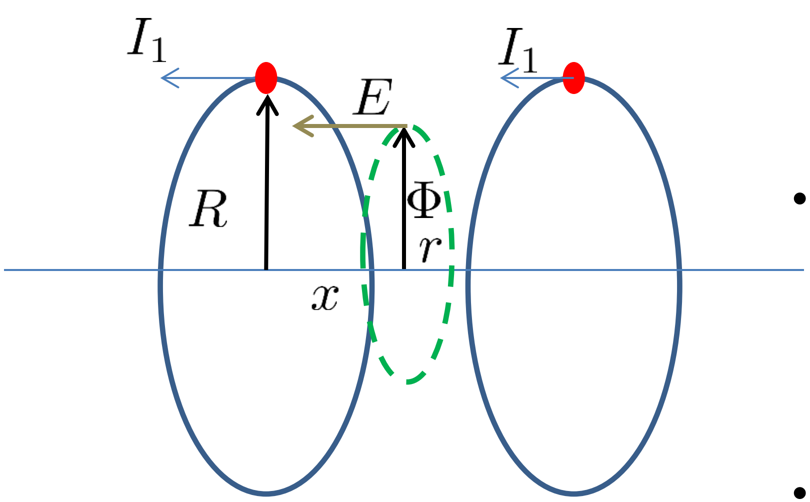
FLARE Driver Coil Design

Yang Ren

Driver Coil Design Basis

- The stored energy for the driver coil is fixed, i.e. $E_{store} = \frac{1}{2}CU^2$=constant
- The peak magnetic field energy is also constant, i.e. $E_B = \frac{1}{2}LI^2$=constant where L is the total inductance of the coil system and I is the total current into the coil system
- Considering a simple two-coil system:



$$2 \times \frac{1}{2}L_1 I_1^2 = \text{constant}$$

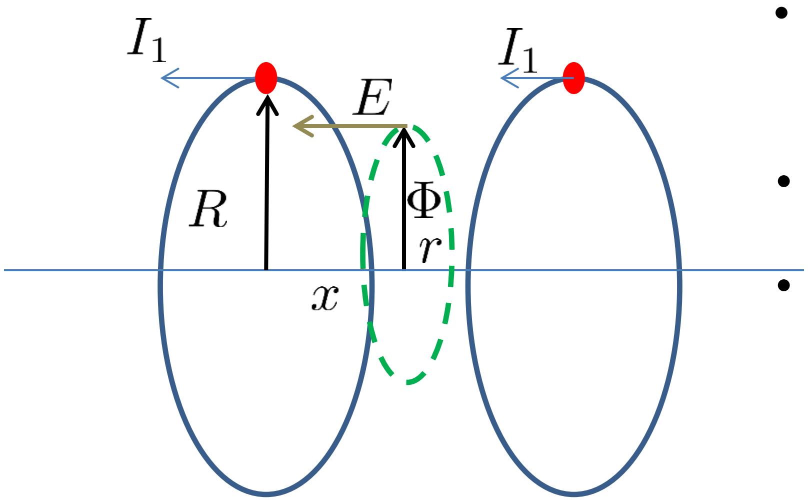
$$\omega = \frac{1}{\sqrt{LC}} \text{ with } L = \frac{L_1^2 - M^2}{2(L_1 - M)} = \frac{1}{2}(L_1 + M)$$

- $E = \frac{1}{2\pi r}\omega\Phi = \frac{1}{\sqrt{LC}} I F(R, x) \propto \frac{1}{\sqrt{L}}\frac{1}{\sqrt{L}}F(R, x) = \frac{1}{L}F(R, x)$ where L is a function of R and x as well.

- Note that the turns in the a single coil, if connected parallelly, do not affect the above results since they are tightly coupled

Simple Model with Free-space Coils

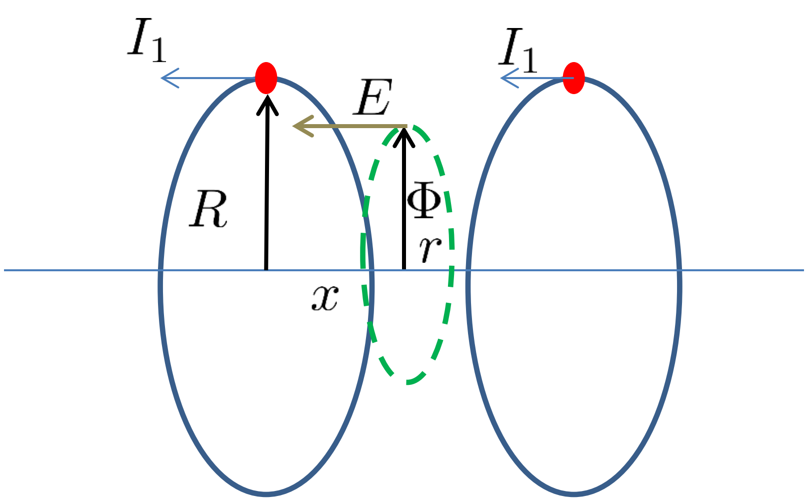
- $L_1 \approx \mu_0 R(ln(8R/a) - 2)$
- $B(r = 0, x, R) \propto \frac{R^2}{(R^2+x^2)^{3/2}} I_1$, assuming uniform B
- Remember: $E \propto \frac{1}{\sqrt{L}} \frac{1}{\sqrt{L}} F(R, x) = \frac{1}{L} F(R, x) \propto \frac{1}{L_1} \frac{R^2}{(R^2+x^2)^{3/2}}$
- Use $L_1 \propto R$, we get $E \propto \frac{R}{(R^2+x^2)^{3/2}}$



- With fixed x, $R = 0 \rightarrow$ E=0
  $R \rightarrow \infty$ leads to $E = 0$
- A R value would maximize E
- Set thet first derivative WRT R to 0, we obtain $R = \frac{x}{\sqrt{2}}$

Coupled Calculation with Maxwell

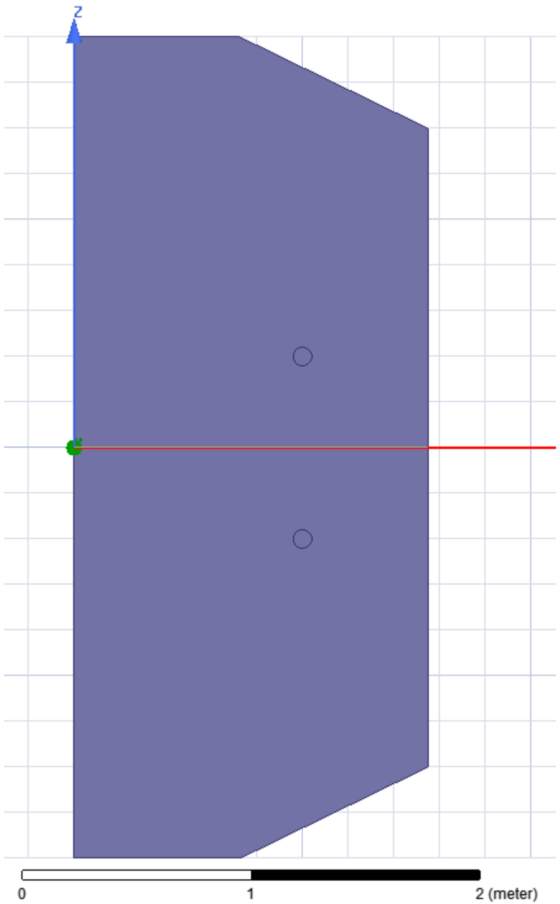
- L_1 and M are calculated with Maxwell with different R and x
- $B(r, x, R|Z = 0)$ with a fixed current I_1 is recorded from each Maxwell simulation for flux calculation
- Remember: $E \propto \frac{1}{\sqrt{L}} \frac{1}{\sqrt{L}} F(R, x) = \frac{1}{L} F(R, x)$
- Use $L = \frac{1}{2}(L_1 + M)$ ($x = 0, L = L_1$ and $x \to \infty$ leads to $L = L_1/2$)

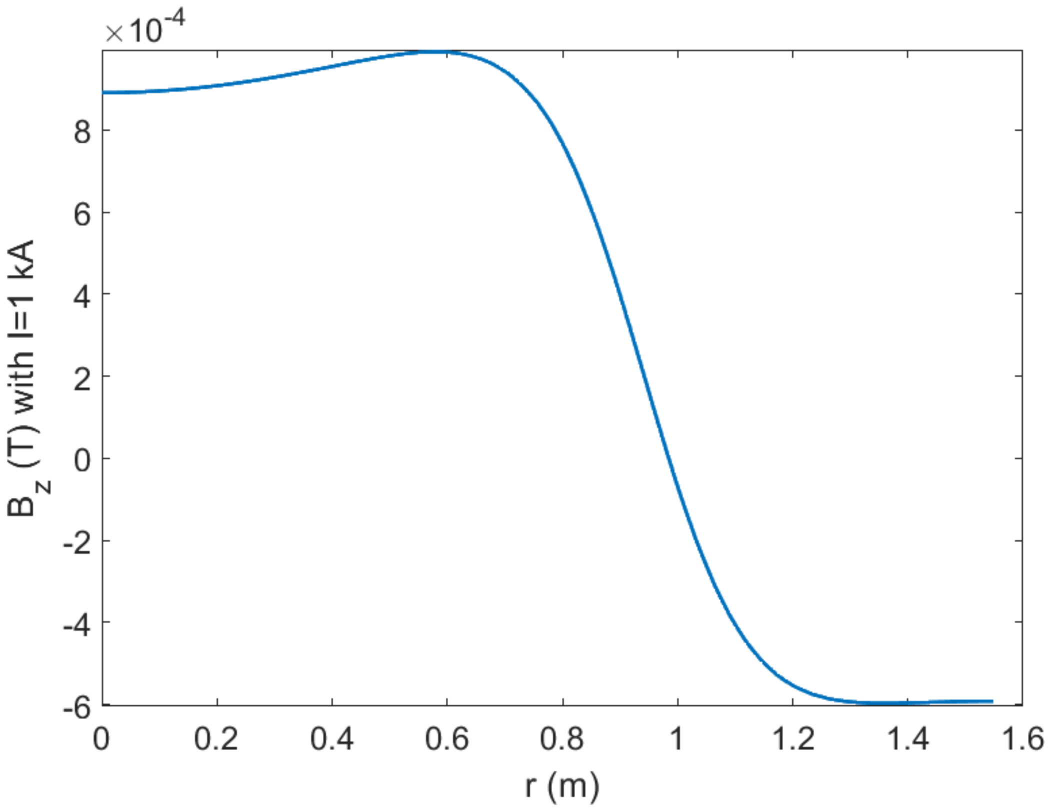


- R from 0.3 to 1.2 m every 5 cm
- x from 0.05 m to 1 m every 5 cm
- Total 380 individual magnetostatic Maxwell calculations

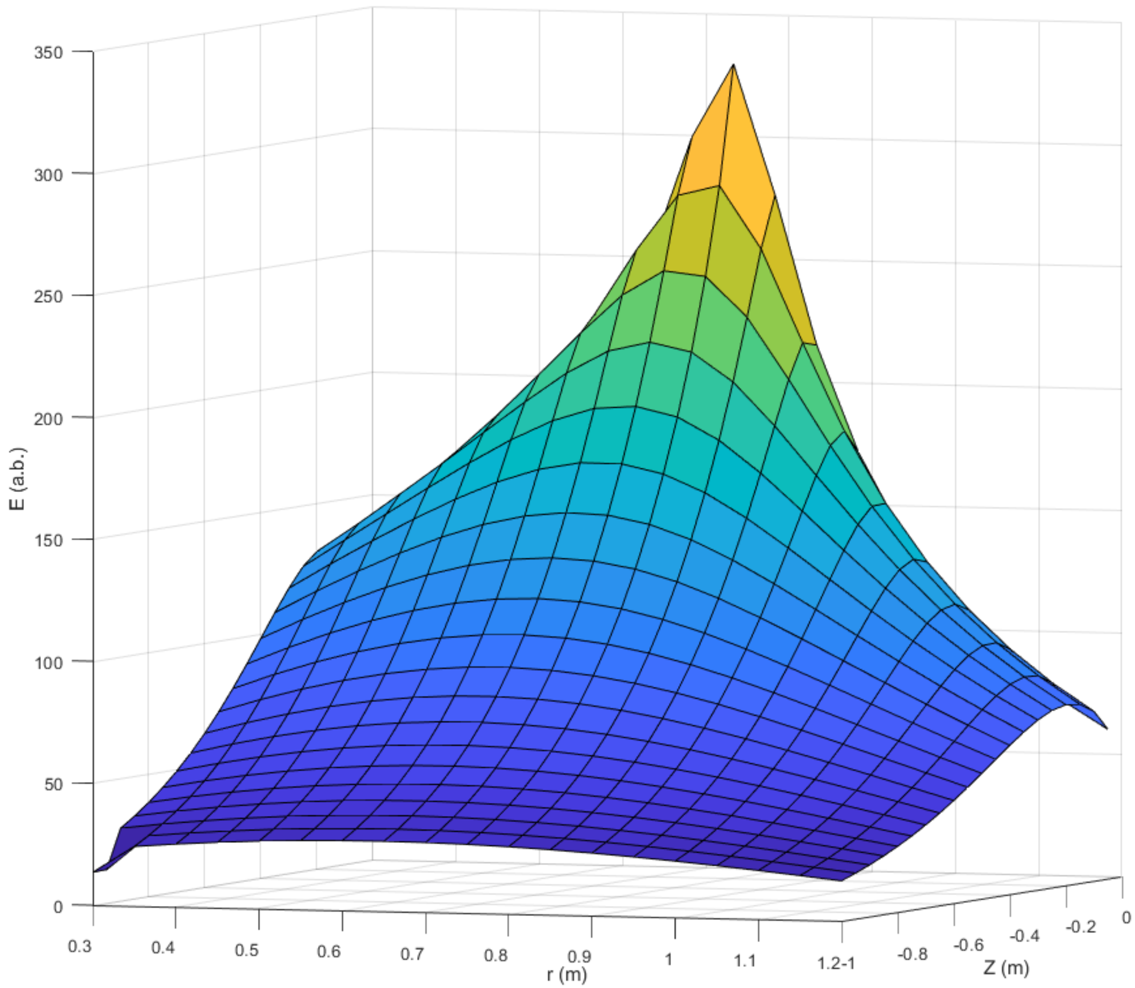
A Typical Maxwell Calculation

- With $R = 0.95$ m and $x = 0.3$ m, $L_1 = 3.8\ \mu H$ and $M = 0.5\ \mu H$
- Magnetic field B at Z=0:





Electric Field Distribution



Electric Field Distribution (cont.)