

1. - Use separation of variables  
- solution for  $x$ -direction

$$\text{is } X(x) = A e^{-\kappa x} + B e^{\kappa x}$$

- must go to zero @  $x = \infty$

$$\Rightarrow X(x) = A e^{-\kappa x}$$

$$\frac{1}{X} \frac{d^2 X}{dx^2} = \kappa^2 = C_1$$

$$\frac{1}{Y} \frac{d^2 Y}{dY^2} = -\left(\frac{3\pi}{a}\right)^2 = C_2$$

$$C_1 + C_2 = 0 \Rightarrow \kappa = 3\pi/a$$

$$V(x, y) = \sin\left(\frac{3\pi y}{a}\right) e^{-3\pi x/a}$$

( $e^0 = 1$  so already normalized)

2. a. General solution

$$V(r, \theta) = \sum (A_n r^n + B_n / r^{n+1}) P_n(\cos \theta)$$

$$\Rightarrow \begin{aligned} V_{in}(r, \theta) &= V_0 \frac{r}{R} \cos \theta \\ V_{out}(r, \theta) &= \frac{V_0 R^2}{r^2} \cos \theta \end{aligned}$$

$$b. \vec{E} = -\nabla V$$

$$\vec{E}_{in}(r, \theta) = -\frac{V_0}{R} \cos \theta \hat{r} + \frac{V_0}{R} \sin \theta \hat{\theta}$$

$$\vec{E}_{out}(r, \theta) = \frac{2V_0 R^2}{r^3} \cos \theta \hat{r} + \frac{V_0 R^2}{r^3} \sin \theta \hat{\theta}$$



$$2c. \vec{D} = \epsilon_0 \vec{E} + \vec{P}$$

$$\vec{D}_{in} = \left( \rho - \frac{\epsilon_0 V_0}{R} \right) \cos \theta \hat{r} + \left( \rho + \frac{\epsilon_0 V_0}{R} \right) \sin \theta \hat{\theta}$$

$$\vec{D}_{out} = \frac{2 \epsilon_0 V_0 R^2}{r^3} \cos \theta \hat{r} + \frac{\epsilon_0 V_0 R^2}{r^3} \sin \theta \hat{\theta}$$

$$d. D_{in-r}|_R = D_{out-r}|_R$$

$$\Rightarrow \rho - \frac{\epsilon_0 V_0}{R} = \frac{2 \epsilon_0 V_0}{R}$$

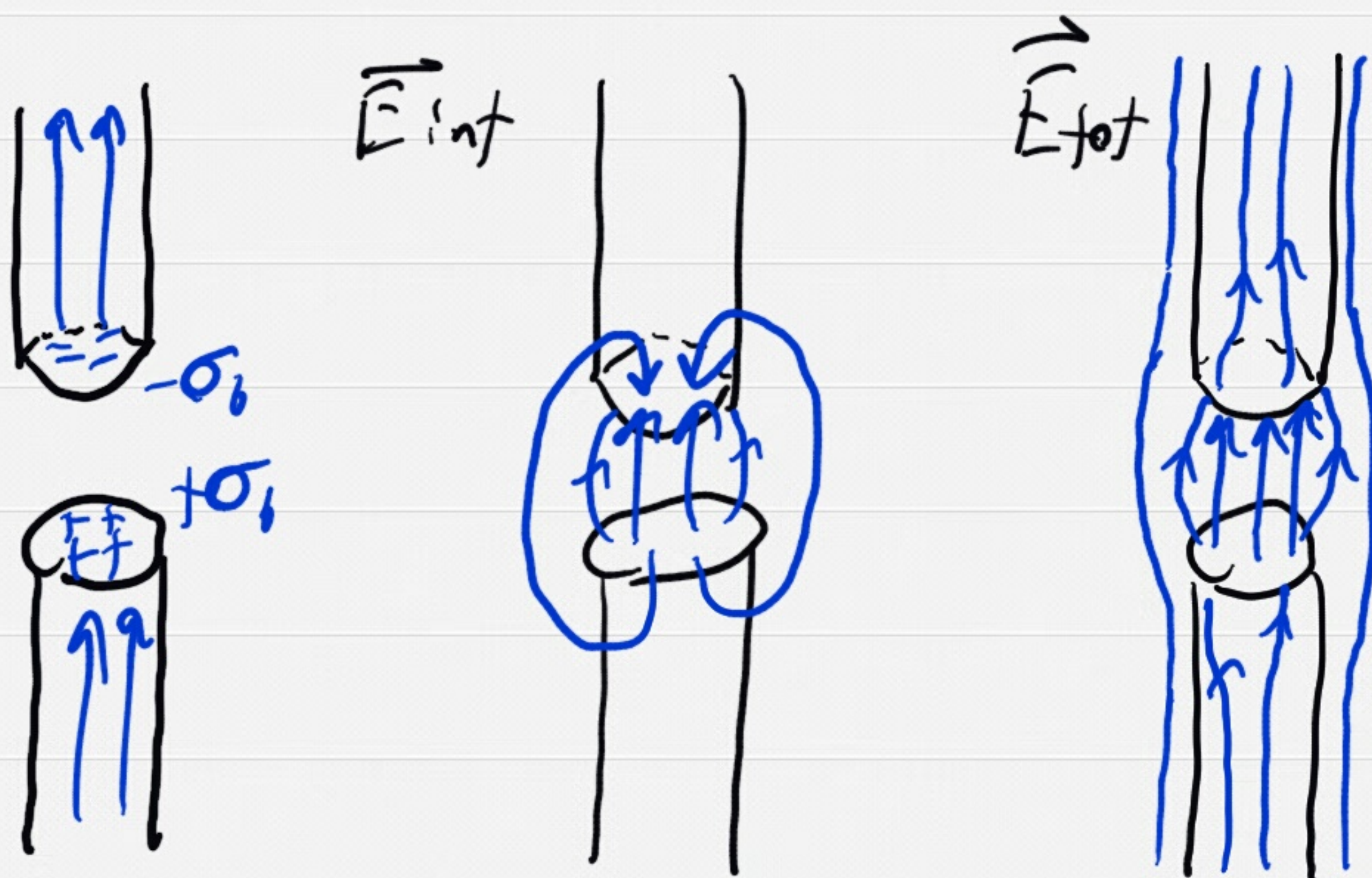
$$\Rightarrow \rho = \frac{3 \epsilon_0 V_0}{R}$$

$$\begin{aligned} 3. \vec{p} &= \int \vec{r}' \rho(\vec{r}') d\tau' \\ &= 3q \left[ \frac{d}{2}, 0 \right] + q \left[ -\frac{d}{2}, 0 \right] \\ &= qd \hat{x} \end{aligned}$$



4.

$\vec{D}$



5. Parallel currents attract  
 $\Rightarrow$  magnetic forces  
compress the coil