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$$V(\vec{r}_p) = \frac{1}{4\pi\epsilon_0} \frac{\vec{p} \cdot \hat{r}_{ip}}{r_{ip}^2}$$

$$\vec{p} = \sum_{i} q_i \vec{r}_i$$

$$V(\vec{r}_p) = \frac{1}{4\pi\epsilon_0} \int \left[ \frac{\vec{p} \cdot \hat{r}_{ip}}{r_{ip}^2} \right] d^3r_i$$

$$\vec{p} = \frac{\vec{p}}{\text{unit vol}}$$

all  $q_i$

$$\vec{\nabla}_i \left( \frac{1}{r_{ip}} \right) = \frac{\hat{r}_{ip}}{r_{ip}^2}$$

$$V = \frac{1}{4\pi\epsilon_0} \sum_{i} \vec{p} \cdot \vec{\nabla}_i \left( \frac{1}{r_{ip}} \right) d^3r_i$$

$$\vec{\nabla}_i \cdot \left( \frac{\vec{P}}{r_{ip}} \right) = \frac{1}{r_{ip}} \vec{\nabla}_i \cdot \vec{P} + \vec{P} \cdot \vec{\nabla}_i \left( \frac{1}{r_{ip}} \right)$$

$$V(r_{ip}) = \frac{1}{4\pi\epsilon_0} \int \frac{1}{r_{ip}} \vec{\nabla}_i \cdot \vec{P} d^3r$$

$$= \frac{1}{4\pi\epsilon_0} \int \vec{\nabla}_i \left( \frac{\vec{P}_i}{r_{ip}} \right) d^3r$$

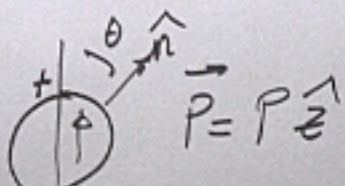
$$\sigma_b = \vec{P} \cdot \hat{n}$$

$$\rho_b = -\vec{\nabla} \cdot \vec{P}$$

$$\text{if } \vec{P} \text{ const; } \rho_b = 0$$



$\vec{E}$



$$P_b = 0 \quad (\neq \vec{P} \cdot \hat{n})$$

$$G_b = \vec{P} \cdot \hat{n} = P \cos \theta$$

in  $V(r, \theta) = \sum_{n=0}^{\infty} A_n r^n P_n(\cos \theta)$

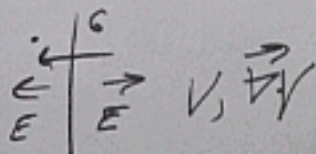
out  $V(r, \theta) = \sum_{n=0}^{\infty} \frac{B_n}{r^{n+1}} P_n(\cos \theta)$

$$\textcircled{a} r=a, V_{in} = V_{out}$$

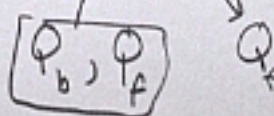
$$\sum_{n=0}^{\infty} A_n a^n P_n(\cos\theta) = \sum_{n=0}^{\infty} \frac{B_n}{a^{n+1}} P_n(\cos\theta)$$

$$A_n a^n = \frac{B_n}{a^{n+1}} \Rightarrow B_n = A_n a^{2n+1}$$

$$\frac{2V_{out}}{2r} - \frac{2V_{in}}{2r} = -\frac{\epsilon}{\epsilon_0}$$



A diagram showing a vertical line with a horizontal line intersecting it. The vertical line has an arrow pointing left labeled 'E' and an arrow pointing right labeled 'E'. The horizontal line has an arrow pointing up labeled 'i' and an arrow pointing right labeled 'V<sub>1</sub>' and 'V<sub>2</sub>'.

$$\vec{D} = \epsilon_0 \vec{E} + \vec{P}$$


$$\vec{E}_{in} = \frac{C}{3\epsilon_0} [-\cos\theta \hat{r} + \sin\theta \hat{\theta}]$$

$$\hat{z} \quad \vec{E}_{in} = \frac{-C}{3\epsilon_0} \hat{z}$$

$$\vec{P} = C \hat{z} \quad \vec{P} = 0$$

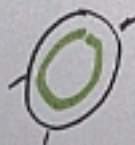
$$\vec{D} = -\frac{C}{3} \hat{z} + C \hat{z} = \frac{2}{3} C \hat{z}$$

$$\vec{P} = \epsilon_0 \vec{E}$$

$$\vec{\nabla} \cdot \vec{D} =$$

$$P_b = -3C \quad \phi_b = Cr$$

$$\vec{E}_{in}, \vec{E}_{out}$$



$$\oint \vec{E} \cdot d\vec{l} = \frac{Q_{enc}}{\epsilon_0}$$

$$\Phi_E = E (4\pi r^2)$$

$$Q_{enc} = \frac{1}{\epsilon_0} (-3C) \frac{4\pi r^3}{3}$$

$$= -\frac{C}{\epsilon_0} \cdot 4\pi r^3$$

$$\vec{E}_{in} = -\frac{C}{\epsilon_0} r \hat{r}$$

$$\text{out } Q_{\text{enc}} = (-3C) \cdot \frac{4}{3}\pi a^3$$

$$+ Ca(4\pi a^2)$$

$$= C4\pi(0)$$

$$\Rightarrow \vec{E}_{\text{out}} = \vec{0}$$

$$D = \epsilon E + P$$

$$\text{out: } \vec{P} = \vec{0}$$

$$\Rightarrow$$

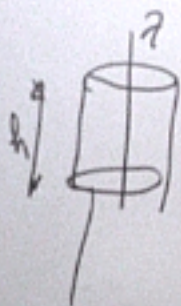
$$\therefore \vec{D}_{\text{out}} = 0$$

$$\text{in: } \vec{E} = -\frac{C}{\epsilon_0} r \hat{r} \quad \vec{P} = Cr = Cr r \hat{r}$$

$$\vec{D} = -\epsilon Cr \hat{r} + Cr r \hat{r} = \vec{0}$$

$$\frac{C \cdot m}{m^3} = \frac{C}{m^2}$$

$$\oint \vec{D} \cdot d\vec{A} = Q_{\text{enc}}$$



$\rho?$

$$\int_V \vec{D} \cdot d\vec{A} = Q_{f, \text{enc}}$$

$$D(2\pi sh) = \lambda h$$

$$\vec{D} = \frac{\lambda}{2\pi s} \hat{s}$$

$\leftarrow \quad \rightarrow$

out

$$\int_V \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\epsilon_0}$$

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wed

$$\vec{E} = \frac{\lambda}{2\pi \epsilon_0 s} \hat{s}$$