Consider a long thin cylindrical rod of uniform charge density (charge per volume) ρ. The rod has radius s and length $50s$.

(a) Find the rod's linear charge density.

(b) What is the (approximate) electric field at point B? Point B is a distance $2s$ from the edge of the rod, near the middle. Hint: Use Gauss' law, taking advantage of the fact that the rod is *very* long as compared to B's distance from the rod.

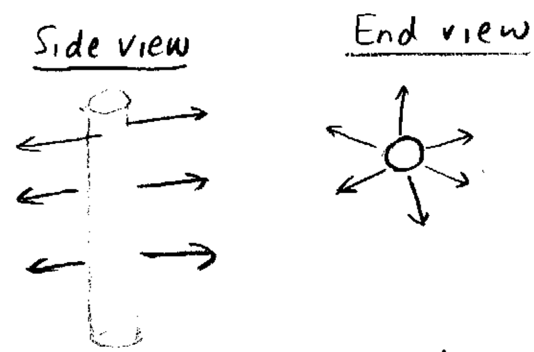
(c) Suppose a small particle of charge q_1 is placed at point B. What electric force acts on that particle?

a) λ = linear chg density = $\dfrac{\text{charge}}{\text{length}}$

Know $\rho = \dfrac{\text{charge}}{\text{vol}} = \dfrac{\text{charge}}{\text{length} \cdot \text{area}}$

$\lambda = \rho \cdot A = \underline{\underline{\rho \pi s^2}}$

b) Apply steps:



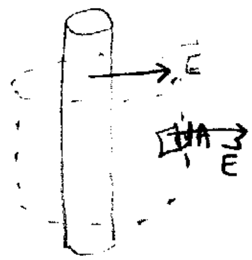
Step 1: Draw the field lines

radial field, by cylindrical symmetry.
(infinitely long)
↳ components up and down cancel

Step 2 Gaussian surface is cylinder concentric with rod at radius r from center, length L

Step 3 Gauss' Law $\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\varepsilon_0}$

On our Gaussian cylinder, the flux through the ends is zero, since field lines are $\parallel$ to ends. But on the cylinder's side, $\vec{E}$ is $\perp$ to $d\vec{A}$, and $|\vec{E}|$ is also constant in magnitude



LHS of Gauss' Law

So $\oint_{cyl} \vec{E} \cdot d\vec{A} = \int_{side} E \cdot dA = E \underbrace{\int_{side} dA}_{\text{surface area of side}} = E \cdot 2\pi r L$

Step 4 RHS of Gauss' Law

$$q_{in} = \lambda \cdot L = \rho \pi s^2 L$$

Step 5 : LHS = RHS

$$E \cdot 2\cancel{\pi} r \cancel{L} = \frac{\rho \cancel{\pi} s^2 \cancel{L}}{\varepsilon_0}$$

$$E = \frac{\rho s^2}{\varepsilon_0 2 r}, \quad \vec{E}(r) = \frac{\rho s^2}{\varepsilon_0 2 r} \hat{r}$$

At $2s$ from edge, $r = 3s \Rightarrow \boxed{\vec{E} = \frac{\rho s}{6 \varepsilon_0} \hat{r}}$

c) $\vec{Force} = q\vec{E} \Rightarrow \boxed{\vec{F}_{\substack{on \\ q_1}} = \frac{q_1 \rho s}{6 \varepsilon} \hat{r}}$