A PROTON (CHARGE 1.60×10^{-19} C, MASS 1.67×10^{-27} kg) IS PLACED 18cm FROM A ROD OF UNIFORM CHARGE DENSITY $\lambda = 5\times10^{12}\ \mathrm{C\,m^{-1}}$. THE INITIAL VELOCITY OF THE CHARGE IS $1.5\ \mathrm{km\,s^{-1}}$ TOWARDS THE ROD BUT IT STOPS AT A DISTANCE b FROM THE ROD. KINETIC ENERGY IS $\frac{1}{2}mv^2$ FOR MASS m MOVING AT VELOCITY v.

(1) WHAT IS THE ELECTRIC FIELD OF THE ROD?

(2) HENCE: WHAT IS THE DISTANCE b?

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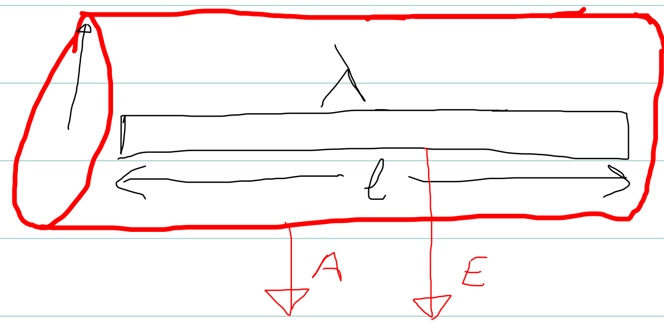
(1) E-FIELD OF ROD



area of body of cylinder $= 2\pi r \ell$

CHOOSE A GAUSSIAN CYLINDER SO $E.dA$ IS ALWAY EA BECAUSE $\cos\theta = \cos 0 = 1$

THEN GAUSS'S LAW STATES $\int \vec{E}.d\vec{A} = \int E\,dA\cos\theta = \int E\,dA = E\int dA = Q/\varepsilon_0$

$$\Rightarrow E\,2\pi r\ell = Q/\varepsilon_0 \Rightarrow E = \frac{Q}{2\pi r\ell\varepsilon_0} = \frac{\lambda}{2\pi r\varepsilon_0}$$

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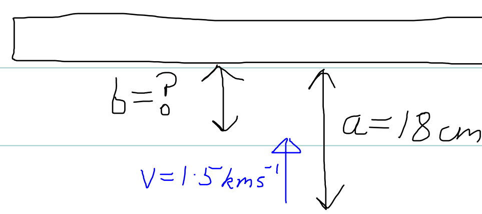
(2) THE DISTANCE b



POTENTIAL ENERGY LOST = KINETIC ENERGY GAINED

$$\Rightarrow \Delta k = -\Delta U \Rightarrow \tfrac{1}{2}mv^2 = q(V_b - V_a) \Rightarrow V_b - V_a = \frac{\frac{1}{2}mv^2}{q} = 0.0117\,V$$

$$V_b - V_a = \int_b^a \vec{E}.d\vec{l} = \int_b^a E_r\,dr = \frac{\lambda}{2\pi\varepsilon_0}\int_{r_b}^{r_a}\frac{dr}{r} = \frac{\lambda}{2\pi\varepsilon_0}\ln\frac{r_a}{r_b} = 0.0117\,V \Rightarrow r_a = r_b\,e^{\frac{2\pi\varepsilon_0}{\lambda}(V_b - V_a)}$$

$$\Rightarrow r_b = r_a e^{-\frac{2\pi\varepsilon_0 (V_b - V_a)}{\lambda}} = 0.158\,m$$