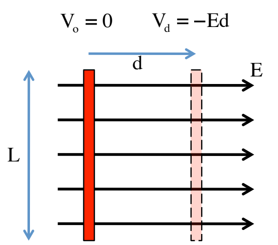
Problem 25.9

The rod starts from rest. How fast is it moving after traveling 2 meters?



$\lambda = 40\text{x}10^{-6}$ C/m, $\mu = .1$ kg/m

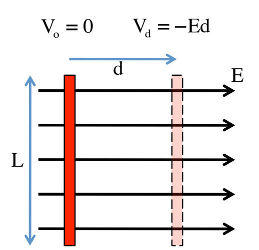
a.) Assume the electrical potential is zero at the initial point. As positive charges travel from higher to lower voltage, the voltages to the right will be negative (i.e., less than zero). In any case, after traveling a distance "d", we can write

$$\Delta V = -\vec{E} \bullet \vec{d}$$
$$\Rightarrow \quad (V_d - 0) = -Ed$$

Using this, the definition of electrical potential and knowing that the amount of charge q on a rod of length L is λL, we can additionally write:

$$V_d = \frac{U_d}{q} = -Ed$$
$$\Rightarrow \quad U_d = -qEd$$
$$\Rightarrow \quad U_d = -(\lambda L)Ed$$

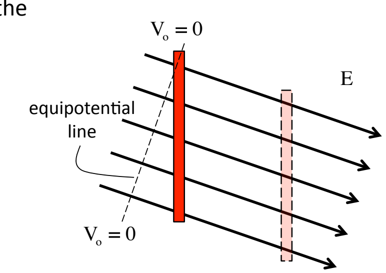
With the potential energy known in general, we can use *conservation of energy* to solve the problem. Doing so,



$\lambda = 40\text{x}10^{-6}$ C/m, $\mu = .1$ kg/m

$$\sum KE_1 + \sum U_1 + \sum W_{ext} = \sum KE_2 + \sum U_2$$
$$0 \quad + \cancel{qV_1}^{\,0} \quad + \quad 0 \quad = \frac{1}{2}mv_d^2 + qV_d$$
$$\Rightarrow \quad 0 = \frac{1}{2} \; m\, v_d^2 + \quad U_d$$
$$\Rightarrow \quad 0 = \frac{1}{2}(\mu L)v_d^2 + (-\lambda L E d)$$
$$\Rightarrow \quad \frac{1}{2}(\mu L)v_d^2 = (\lambda L E d)$$
$$\Rightarrow \quad v_d = \left(2\left(\frac{\lambda}{\mu}\right)Ed\right)^{1/2}$$
$$\Rightarrow \quad v_{d=2} = \left(\frac{2(40\text{x}10^{-6}\text{C/m})(100\text{N/C})(2\text{m})}{(.1\text{ kg/m})}\right)^{1/2}$$
$$\Rightarrow \quad v_{d=2} = .4 \text{ m/s}$$

b.) How would the problem have changed if the field was not perpendicular to the rod?



Although each piece of the rod would now start out at a different voltage point (equipotential lines are perpendicular to the electric field, so the top end of the rod would be at V = 0 but the bottom end wouldn't be), each piece of the rod would still travel 2 meters, would experience the same *voltage change* over that distance and, hence, would have the same amount of work done on it as was the case in the original scenario. In other words, nothing would change and there will be no difference under this circumstance.