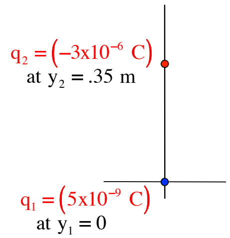
Problem 25.14

Consider the charges located as shown:



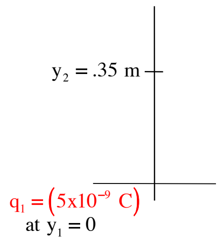
a.) What is the electrical potential energy of the system?

There is no energy requirement to bring the first charge in from infinity. Bringing in the second charge requires work. That value is the amount of energy in the system. To start, the electrical potential at .35 due to the charge at the origin is:

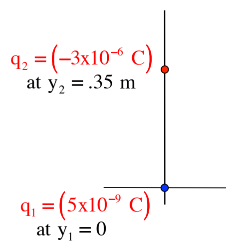
$$V_{.35} = k\frac{q_1}{|y_2|}$$

$$= \left(9x10^9\ N\bullet m^2/C^2\right)\frac{\left(5x10^{-9}\ C\right)}{(.35\ m)}$$

$$\Rightarrow \quad V_{.35} = 1.29x10^2\ \text{volts}$$



Work is required in bringing the second charge to its position. We know the work done by the field on a charge is related to the *potential energy change* between the start and stop position. Assuming that the voltage at infinity is zero, the work the field does is:



$$\frac{W_{field}}{q} = -\Delta V$$

$$\Rightarrow \quad W_{field} = -q\Delta V = -q\left(V_{.35} - V\infty\right)$$

$$\Rightarrow \quad W_{field} = -\left(-3x10^{-9}C\right)\left(129V - 0\right)$$

$$= 3.86x10^{-7}\ J$$

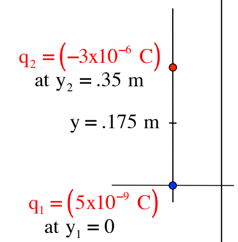
The work *you* have to do to get the charge in from infinity, which equals the energy stored in the system, will be *minus* that amount, or.

$$\text{energy of system} = -3.86x10^{-7}\ J$$

This all makes perfect sense. The charge at the origin is positive. The charge being brought in from infinity is negative. The negative charge will want to pick up speed due to its presence in the positive charge's electric field, so that field will do positive work on the negative charge. The total work being done (according to the work/energy theorem) must be zero as the KE of the system isn't supposed to change. That means the work *you* do (which equates to the energy the system has by the time you are done) must be negative. The negative sign also means you would have to do work to make the charge separation greater.

b.) What is the electrical potential midway between the charges?

Electrical potentials add like scalars, so we can write:



$$V_{.175} = k\frac{q_1}{r_1} + k\frac{q_2}{r_2}$$

$$= \quad k \quad \frac{q_1 + q_2}{r}$$

$$= \left(9x10^9\ N\bullet m^2/C^2\right)\frac{\left(5x10^{-9} + \left(-3x10^{-9}\right)\right)C}{(.175\ m)}$$

$$\Rightarrow \quad V_{.35} = 103\ \text{volts}$$