Below are two particles with +0.1 µC and -0.1 µC charges separated by 0.5 mm (1 µC = 10⁻⁶ C). You will calculate the electric field on the axis in two ways. First superimposing the electric fields from point charges, and second by modeling the plus and minus charges as an electric dipole.

a) Using superposition, calculate the x and y-components of the electric field at the point indicated below on the axis of the charges. Do not use any approximations.

\[ E_y = 0 \text{ because } E\text{-field points directly toward - and directly away from + charges.} \]

\[ E_x = \left( 9 \times 10^9 N \cdot m^2 / C^2 \right) \left( 10^{-7} C \right) \left( \frac{1}{(1 \times 10^{-3} m)^2} - \frac{1}{(1.5 \times 10^{-3} m)^2} \right) = 5.0 \times 10^8 N / C \]

\[ E_x = \]

\[ E_y = \]

c) Calculate the electric field at the point indicated above using the dipole approximation for electric fields on the axis, \[ |\vec{E}| = k2p / r^3. \]

The magnitude of the dipole moment is \[ |\vec{p}| = qs = (0.1 \mu C)(0.5 \times 10^{-3} m) = 5 \times 10^{-11} C \cdot m. \] The approximate electric field is then

\[ |\vec{E}| = \left( 9 \times 10^9 N \cdot m^2 / C^2 \right) \left( 5 \times 10^{-11} C \cdot m \right) \left( 1.25 \times 10^{-3} m \right)^3 = 4.61 \times 10^8 N / C \]

\[ E_x = \]

\[ E_y = \]
c) Explain similarities / differences between these two calculations.

The approximation for dipole electric fields is good only when the point at which the electric field is evaluated is much farther from the dipole than the dipole separation. Here the point is twice the dipole separation, and the approximation works reasonably well, but is not perfect.

d) Sketch graphs of $E_x$ and $E_y$ vs position along the dashed vertical line indicated below. For example, the point $y=0$ mm is the point at which you calculated the field components in parts $a)$ and $b)$.