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Two point charges are at fixed positions along the x-axis. Find the magnitude and direction (left or right) of the net electric field at the origin that is produced by these two charges. The charges have values \(q_1 = -2.0 \times 10^{-6} C\) and \(q_2 = 4.0 \times 10^{-6} C\). \(q_1\) is at \(x = .10 m\) and \(q_2\) is at \(x = -.20 m\).

Equation:
\[
\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2}
\]

Knowns:
\(q_1 = -2 \times 10^{-6} C\)
\(r_1 = .1 m\)
\(q_2 = 4 \times 10^{-6} C\)
\(r_2 = -.2 m\)

Unknowns:
\(\vec{E}\) at \(x=0m\)

Algebra and PnP:
Electric fields leave positive charges and go to negative charges. The negative charge on the right and the positive charge is on the left, so the electric field must be headed to the right.
\[
\vec{E} = \frac{1}{4\pi\varepsilon_0} \left( \frac{q_1}{r_1^2} + \frac{q_2}{r_2^2} \right)
\]
\[
\vec{E} = \frac{1}{4\pi\varepsilon_0} \left( \frac{2 \times 10^{-6} C}{(.1 m)^2} + \frac{4 \times 10^{-6} C}{(.2 m)^2} \right)
\]
\[
\vec{E} = 8987551787.3683 \text{ m} \cdot \text{C}^{-1} \cdot \text{m}^{-1}
\]
\[
\vec{E} = 2.70 \times 10^6 \text{ N} \cdot \text{C}^{-1} \cdot \text{m}^{-1}
\]

Consider two charges .2m apart. The charge on the right is 3nC and the charge on the left is -6nC. What is the long range behavior of the electric field? What are the directions of the electric field in the regions to the left and right of the charges? Where does the electric field equal to \(0 \text{ N} \cdot \text{C}^{-1} \cdot \text{m}^{-1}\)?

Knowns:
\(q_1 = 3nC\)
\(q_2 = -6nC\)
\(d = .2 m\)

Unknowns:
Long range electric field

Directions of electric field next to charges on either side
Location of no electric field

Equation:
\[
\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{4q}{r^2}
\]

Algebra and PnP:
Long range is dictated by the net charge of -3nC. This means that over most space, the electric field is going to be pointing toward the charges. That is, the signs will be negative on the right and positive on the left. The electric field will point from the positive charge to the negative charge. With the positive charge on the right, that means the electric field will be pointing to the left in between charges or the sign will be negative. The left of the negative charge will behave like the long range behavior since it is the same kind of the charge there as the net charge. To the right of the positive charge, the electric field will be pointing away from it or it be positive there. Since the long range field on the right is negative there must be a crossing point over there. Where is it?

\[ E = \frac{1}{4\pi\varepsilon_0} \left( \frac{-6nC}{(x-2m)^2} + \frac{3nC}{x^2} \right) = 0 \]

\[ E = \frac{-6nC}{(x+2m)^2} + \frac{3nC}{x^2} = 0 \]

\[ 6nCx^2 = 3nC(x + .2m)^2 \]

\[ 2x^2 = x^2 + .4mx + .04m^2 \]

\[ x = \frac{4m \pm \sqrt{16m^2 - 4 \times 1 \times .04m^2}}{2 \times 1} \]

\[ x = -.08284m \text{ or } .4828m \]

Only the positive one is correct. The negative one is on the other side if the positive charge and the sign of the positive charge term will have switched.

A muon enters into a uniform electric with initial perpendicular velocity of .7c. The electric field is 1m long and 5cm wide. It then exits the electric field having moved across the 5cm. How strong is the electric field?

**Knowns:**
- \( h = 5cm \)
- \( l = 1m \)
- \( v_0 = .7c = 2.1 \times 10^8 \frac{m}{s} \)
- \( m_\mu = 1.8835 \times 10^{-28} \text{kg} \)
- \( q = 1.602 \times 10^{-19} \text{C} \)

**Unknowns:**
- \( t, a, E \)

**Equations:**
- \( x = x_0 + v_0 t + \frac{1}{2}at^2 \)
- \( F = ma \)
- \( E = \frac{F}{Q} \)

**Algebra and PnP:**
- \( t = \frac{x}{v_0} \)
- \( t = \frac{1m}{2.1 \times 10^8 \frac{m}{s}} = 4.765 \times 10^{-9} \text{s} \)
- \( a = \frac{2x}{t^2} \)
- \( a = \frac{2 \times .05m}{(4.765 \times 10^{-9} \text{s})^2} = 4.4039 \times 10^{15} \frac{m}{s^2} \)
- \( F = ma \)
- \( F = 1.8835 \times 10^{-28} \text{kg} \times 4.4039 \times 10^{15} \frac{m}{s^2} \)
- \( F = 8.295 \times 10^{-13} \text{N} \)
- \( E = \frac{F}{Q} \)
- \( E = \frac{8.295 \times 10^{-13} \text{N}}{1.602 \times 10^{-19} \text{C}} \)
- \( E = 5.177 \times 10^6 \frac{\text{N}}{\text{C}} \)