PhysicsTutor

Point charges: electric field

Giordano 17.45

Problem:

- Two point particles with charges q_1 and q_2 are separated by a distance L, as shown. The electric field vanishes at A, which is a distance $L/4$ from q_1. What is the ratio q_1/q_2?

Relevant ideas:

Relevant ideas:

- Electric field from a positive point charge q: radially outward, falls with distance r: q/r^2

Relevant ideas:

- Electric field from a positive point charge q: radially outward, falls with distance r: q/r^2
- Electric fields for multiple charges add vectorially (superposition principle). Total **E** represents net force divided by probe charge.

Relevant ideas:

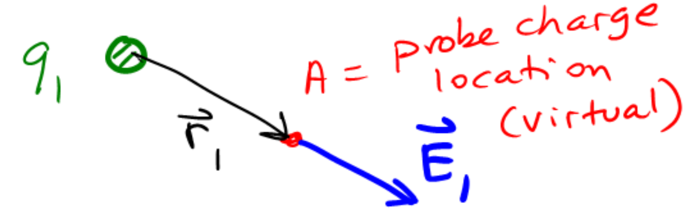
- Electric field from a positive point charge q: radially outward, falls with distance r: q/r^2
- Electric fields for multiple charges add vectorially (superposition principle). Total **E** represents net force divided by probe charge.
- Field from 2 charges is zero at some in-between point: there must be a cancellation. The probe charge is in equilibrium there.

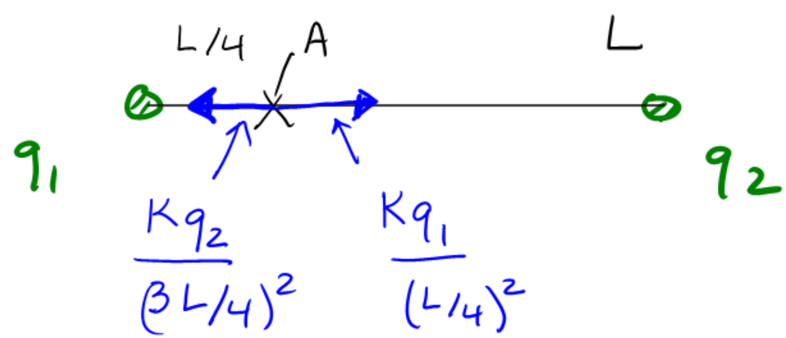
Equations associated with ideas:

$$\vec{F}_{Coulomb} = \underbrace{q_p}_{\text{probe charge}} \vec{E}$$

→ Coulomb force due to q_1 on q_p (virtual)

$$\vec{E}_1 = \frac{1}{4\pi\varepsilon_0} \frac{q_1}{r_1^2} \hat{r}_1$$





magnitudes!

OR: equate the magnitudes

$$E_{1,x} = + \frac{kq_1}{(L/4)^2}$$

$$E_{2,x} = - \frac{kq_2}{(3/4\,L)^2}$$

$$E_{net,x} = E_{1,x} + E_{2,x} = 0$$

vectorial addition.

Strategy

Strategy

- Express the fields at point *A* from charges q_1 and q_2. The distances are given in terms of *L*.

Strategy

- Express the fields at point A from charges q_1 and q_2. The distances are given in terms of L.
- The net field is the sum of the two, and is to be set to zero. Vector addition is key here!

Strategy

- Express the fields at point *A* from charges q_1 and q_2. The distances are given in terms of *L*.
- The net field is the sum of the two, and is to be set to zero. Vector addition is key here!
- This condition should constrain the ratio of the two charges. Name $q_1 = R\, q_2$.

Strategy

- Express the fields at point A from charges q_1 and q_2. The distances are given in terms of L.
- The net field is the sum of the two, and is to be set to zero.
- This condition should constrain the ratio of the two charges. Name $q_1 = R\, q_2$.
- Keep in mind: the same sign of q_1 and q_2 leads to zero net field.

Solution

Solution

- $\frac{K q_1}{(L/4)^2} = \frac{K q_2}{(3L/4)^2}$, $K = \frac{1}{4\pi\varepsilon_0}$

Solution

- $$\frac{\cancel{K} q_1}{(L/4)^2} = \frac{\cancel{K} q_2}{(3L/4)^2} \Big| \cdot L^2 , \quad K = \frac{1}{4\pi\varepsilon_0}$$
- $$q_1 \left(\frac{4}{1}\right)^2 = q_2 \left(\frac{4}{3}\right)^2 \quad \therefore \; q_1/q_2 = 1/3^2 = 1/9$$

Solution

- $\frac{\cancel{K} q_1}{(L/4)^2} = \frac{\cancel{K} q_2}{(3L/4)^2} \Big| \cdot L^2$, $K = \frac{1}{4\pi\varepsilon_0}$
- $q_1 \left(\frac{4}{1}\right)^2 = q_2 \left(\frac{4}{3}\right)^2 \quad \therefore q_1/q_2 = 1/3^2 = 1/9$
- Note: $q_1 \cdot q_2 > 0$ same sign is required, both can be negative

Solution

- $\frac{\cancel{K} q_1}{(L/4)^2} = \frac{\cancel{K} q_2}{(3L/4)^2} \Big| \cdot L^2, \quad K = \frac{1}{4\pi\varepsilon_0}$
- $q_1 \left(\frac{4}{1}\right)^2 = q_2 \left(\frac{4}{3}\right)^2 \quad \therefore \ q_1/q_2 = 1/3^2 = 1/9$
- Note: $q_1 \cdot q_2 > 0$ — same sign is required, both can be negative
- Electric fields from q_1 and q_2 at A (in between) point in opposite directions

$\longrightarrow$ cancellation is possible.

Do not add $\frac{K q_i}{r_i^2}$ naively!