task_5u1zbroaz75w39jk_with_calculation

Student Group

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Exercise E1 Electrostatics I
(written test, approx. 8 % of a 120-minute written test, SS2024)

Given is the arrangement of electric charges in the picture below. The values of the point charges are:

- $q_0=-1 ~\rm nC$
- $q_1=-5 ~\rm nC$

In the beginning, the area charge is $q_4=0 ~\rm nC$.
The permittivity is $\varepsilon_0 = 8.854 \cdot 10^{-12} ~\rm As/Vm$

2. What is the magnitude of the resulting force on q_0?

Path

- $\vec{F}_{01} = \left({\begin{array}{cccc} +917 {~\rm \mu N} \\ 0 \\ \end{array} } \right)$
- $\vec{F}_{02} = \left({\begin{array}{cccc} -1997 {~\rm \mu N} \\ 0 \\ \end{array} } \right)$
- $\vec{F}_{03} = \left({\begin{array}{cccc} 0 {~\rm \mu N} \\ -1123 {~\rm \mu N} \\ \end{array} } \right)$

With all the x and y components, we can calculate the resulting magnitude of the force with the Pythagorean Theorem:

$$\begin{align*} F = |\vec{F}| &= \sqrt{\left(\sum_i F_{i,x} \right)^2 + \left(\sum_i F_{i,y} \right)^2} \\ &= \sqrt{\left(+917 {~\rm \mu N} - 1997 {~\rm \mu N} \right)^2 + \left(-1123 {~\rm \mu N} \right)^2} \\ &= 1560.\;\!.\!.\!.\! {~\rm \mu N} \\ \end{align*}$$

Result

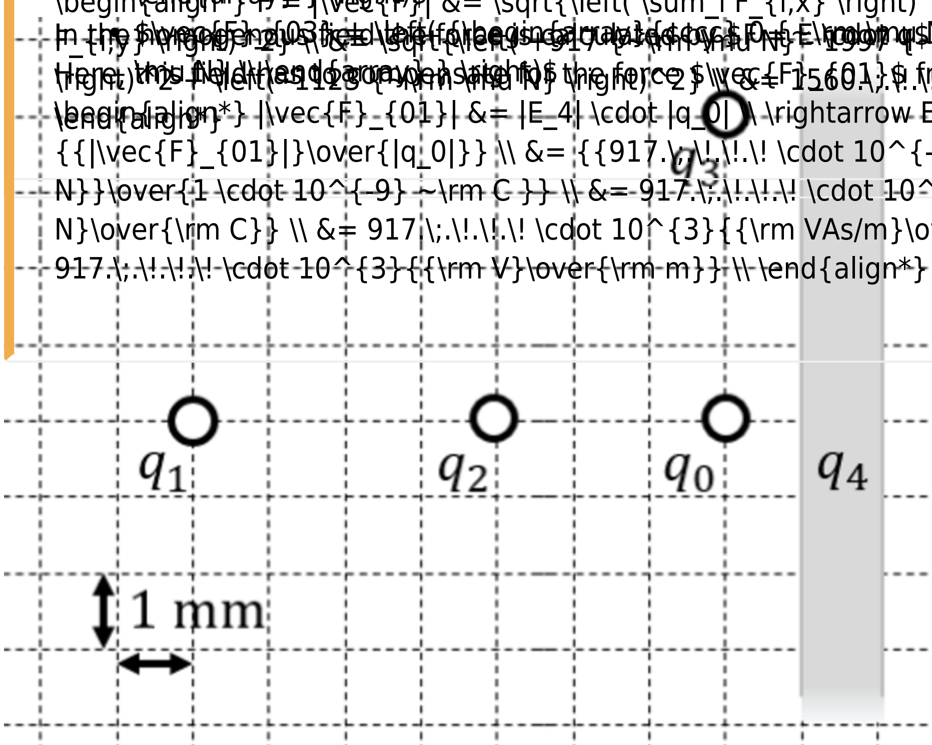
3. Now, the charge q_4 is changed. The area charge q_4 generates a homogenous field E_4. Which value needs E_4 to have to get a resulting force of $0 ~\rm N$ on q_0?

Path

In the homogenous field the force is calculated by $F = E \cdot q$.
Here, this field has to compensate for the force $\vec{F}_{01}$ from q_1 on q_0:

$$\begin{align*} |\vec{F}_{01}| &= |E_4| \cdot |q_0| \\ \rightarrow E_4 &= {{|\vec{F}_{01}|}\over{|q_0|}} \\ &= {{917.\;\!.\!.\!.\! \cdot 10^{-6} {~\rm N}}\over{1 \cdot 10^{-9} ~\rm C }} \\ &= 917.\;\!.\!.\!.\! \cdot 10^{3}{{\rm N}\over{\rm C}} \\ &= 917.\;\!.\!.\!.\! \cdot 10^{3}{{\rm VAs/m}\over{\rm As}} \\ &= 917.\;\!.\!.\!.\! \cdot 10^{3}{{\rm V}\over{\rm m}} \\ \end{align*}$$

$E_4 = 917 {{\rm kV}\over{\rm m}}$



1. Calculate the single forces $\vec{F}_{01}$, $\vec{F}_{02}$, $\vec{F}_{03}$, on the charge q_0!

Path

First, set up a coordinate system. Here, I choose x pointing to the right (positive values to the right) and y pointing upwards (positive values upwards).

Then, calculate the magnitude of the forces, like $\vec{F}_{01}$ (force on q_0 from q_1).
The force $\vec{F}_{01}$ is purely on the x-axis and therefore equal to

$F_{01,x}$. \begin{align*} \vec{F}_{01} = F_{01,x} &= {{1}\over{4\pi\varepsilon}}\cdot {{q_1\cdot q_0}\over{r^2_{01}}} \\ &= {{1}\over{4\pi\cdot 8.854 \cdot 10^{-12} ~\rm As/Vm}}\cdot {{1 \cdot 10^{-9} ~\rm C \cdot 5 \cdot 10^{-9} ~\rm C}\over{(7 \cdot 10^{-3} ~\rm m)^2}} \\ &= 917.\;.\!.\!.\! \cdot 10^{-6} {\rm {{(As)^2 \cdot Vm}\over{As \cdot m^2}}} = 917.\;.\!.\!.\! \cdot 10^{-6} {\rm {{VAs}\over{m}}} = 917.\;.\!.\!.\! \cdot 10^{-6} {\rm {{Ws}\over{m}}} \\ &= +917.\;.\!.\!.\! {\rm \mu N} \end{align*} Since both q_0 and q_1 have the same sign for their charges, they are repelling each other. Therefore, The force $\vec{F}_{01}$ points to the right (positive value).

Similarly, we get for $\vec{F}_{02}$ and $\vec{F}_{03}$ \begin{align*} \vec{F}_{02} = F_{02,x} &= -1997.\;.\!.\!.\! {\rm \mu N} \\ \vec{F}_{03} = F_{03,y} &= -1123.\;.\!.\!.\! {\rm \mu N} \\ \end{align*} Since q_0 and q_2 have the different sign for their charges, they are attract each other. Therefore, The force $\vec{F}_{02}$ points to the left (negative value).
Since q_0 and q_3 have the different sign for their charges, they are attract each other. Therefore, The force $\vec{F}_{03}$ points downwards (negative value).