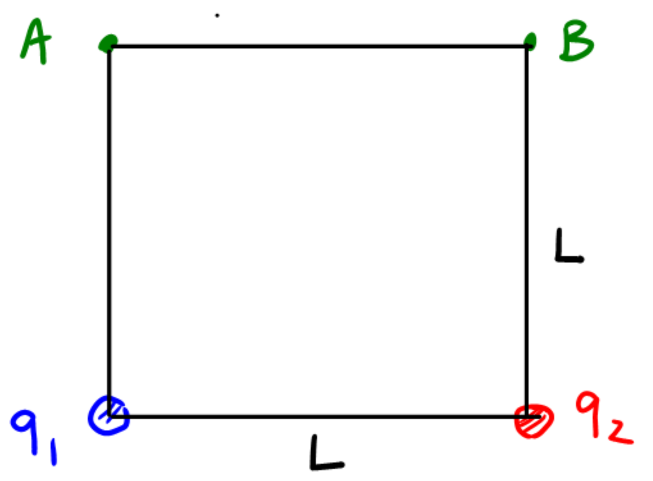
PhysicsTutor

Point charges: electric field

Problem:

- Two point charges, q_1 = - 3.5 nC and q_2 = + 4.5 nC are located at the bottom corners of a square with L = 2.5 cm. What are the magnitude and direction of the electric field at the two top corners of the square, *A* and *B*?



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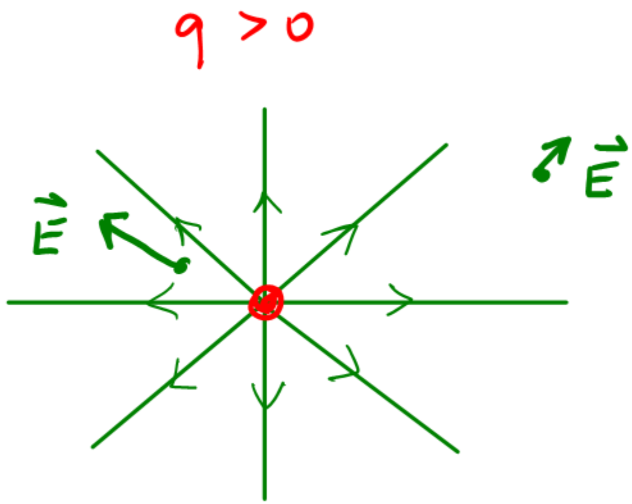

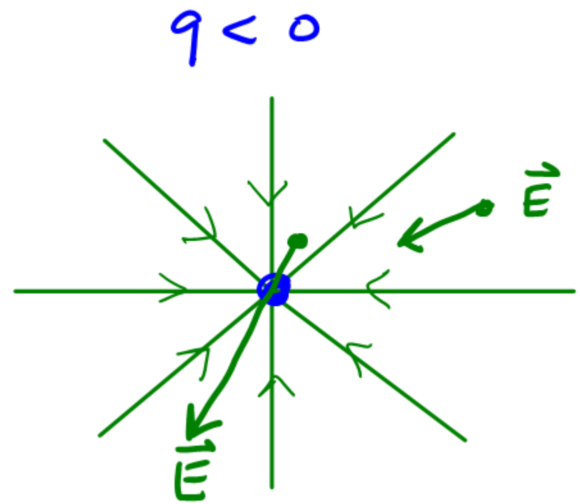

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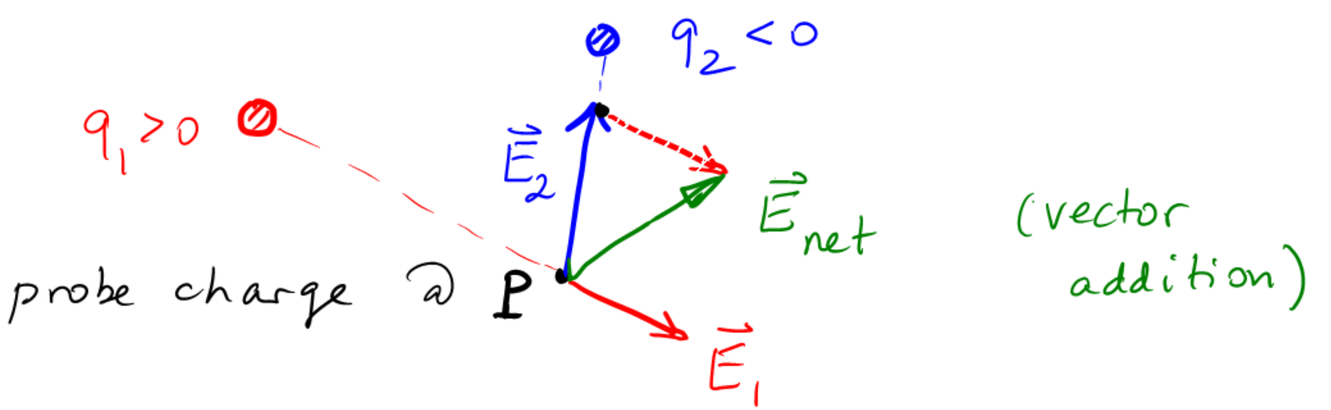
- Electric fields for multiple charges add vectorially (superposition principle). Total **E** represents net force divided by probe charge.



Relevant ideas:

- Electric field from a positive point charge q: radially outward, falls with distance r: Kq/r^2
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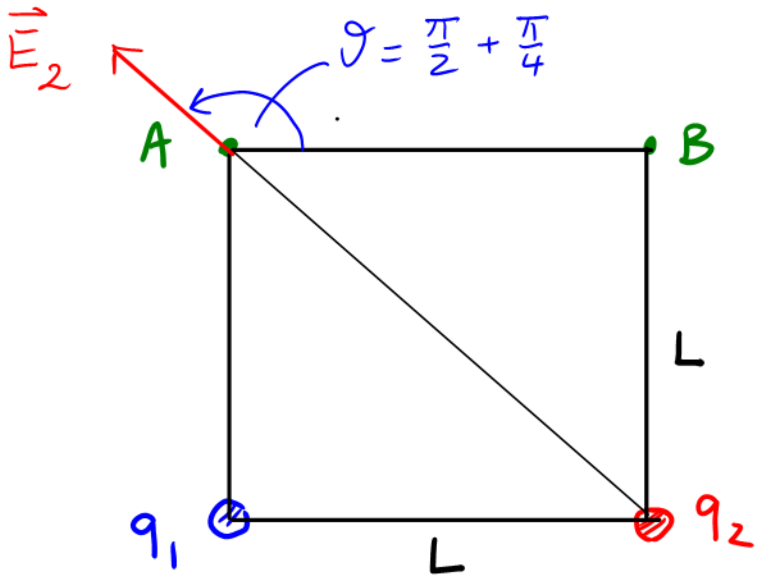
- Use geometry to simplify calculations: work in Cartesian (x,y) coordinates when specifying **E**. Q: symmetry for point B after solving at A???

Equations associated with ideas:



$$|E_2| = \frac{K q_2}{(2L^2)}$$

diagonal : $\sqrt{2}L$

$$K = \frac{1}{4\pi\varepsilon_0} = 9.0 \times 10^9 \frac{Nm^2}{C^2}$$

$$E_{2x} = -E_{2y}$$

direction : $\left(-\frac{\hat{i}}{\sqrt{2}} + \frac{\hat{j}}{\sqrt{2}}\right)$

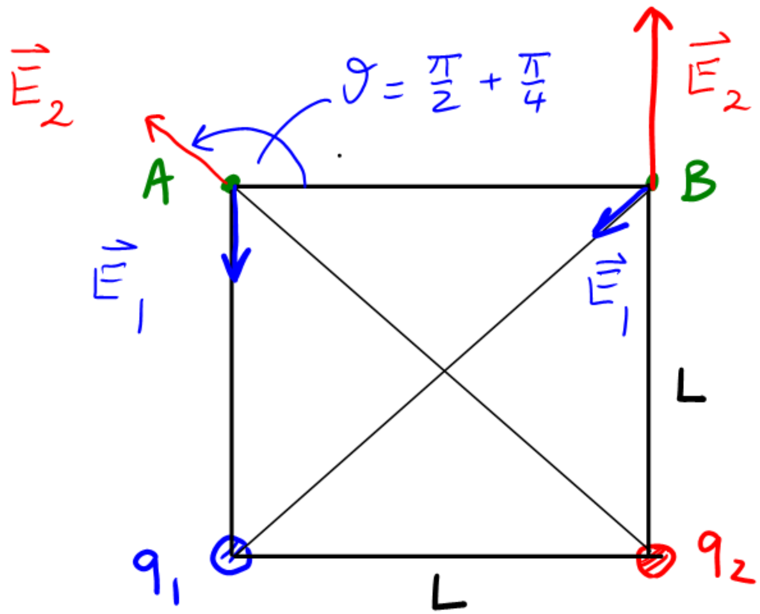
$$\vec{E}_2 = \frac{Kq_2}{2L^2} \frac{1}{\sqrt{2}} (-\hat{i} + \hat{j})$$

Alternative: $E_{2x} = |E_2| \cos\vartheta$, $E_{2y} = |E_2| \sin\vartheta$

ϑ = angle w. +ve x-axis $= 90^\circ + 45^\circ = 135^\circ$

$\cos\vartheta = -\frac{1}{\sqrt{2}}$ $\quad \sin\vartheta = \frac{1}{\sqrt{2}}$

Strategy



no symmetry,

since $q_1 \neq q_2$

(different magnitude)

also: sign difference

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- Convert the result to magnitude and direction, then do the calculation at *B* (no symmetry!)

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- A: $\vec{E}_1 = \frac{-K|q_1|}{L^2}\hat{j}$ $\qquad \vec{E}_2 = \frac{K q_2}{2L^2}\frac{1}{\sqrt{2}}(-\hat{i} + \hat{j})$

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- $\vec{E}_1 = \frac{-9.0 \times 10^9 \cdot 3.5 \times 10^{-9}}{2.5^2 \times 10^{-4}} \frac{N}{C} \hat{j} = -5.04 \times 10^4 \frac{N}{C} \hat{j}$ $\vec{E}_2 = 2.29 \times 10^4 \frac{N}{C} (-\hat{i} + \hat{j})$

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- $\vec{E}^{A}_{net} = (-2.29\hat{i} - 2.75\hat{j})\,10^{4}\frac{N}{C} \rightarrow$ $E^{A}_{net} = 3.58\times10^{4}\frac{N}{C}$, $\vartheta = 50^\circ + 180^\circ = 230^\circ$

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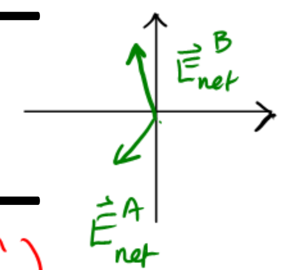
- $\vec{E}^{A}_{net} = (-2.29\,\hat{i} - 2.75\,\hat{j})\,10^{4}\,\frac{N}{C} \rightarrow$ $\quad E^{A}_{net} = 3.58\times10^{4}\frac{N}{C}$, $\quad \vartheta = 50^\circ + 180^\circ = 230^\circ$
- B: $\vec{E}_2 = \frac{Kq_2}{L^2}\hat{j}$ $\quad\quad$ $\vec{E}_1 = \frac{-K|q_1|}{2L^2}\frac{1}{\sqrt{2}}(\hat{i}+\hat{j})$



$\vec{E}_2 = 6.48\times10^{4}\frac{N}{C}\hat{j}$ $\quad\quad$ $\vec{E}_1 = 1.78\times10^{4}\frac{N}{C}(-\hat{i}-\hat{j})$

$\vec{E}^{B}_{net} = (-1.8\,\hat{i} + 4.7\,\hat{j})\times10^{4}\frac{N}{C}$ $\quad\quad$ $E^{B}_{net} = 5.0\times10^{4}\frac{N}{C}$

$\vartheta = -69^\circ + 180^\circ = 111^\circ$

$\vec{E}^{A}_{net}$: $(x-, y-)$ components both negative : 3^{rd} quadrant.

$\vec{E}^{B}_{net}$: x-comp. < 0, y-comp > 0 : 2^{nd} quadrant