FINAL TERM

Physics 1 [Fall 2021-2022]

Department of Physics
Faculty of Science & Technology (FST)
American International University-Bangladesh

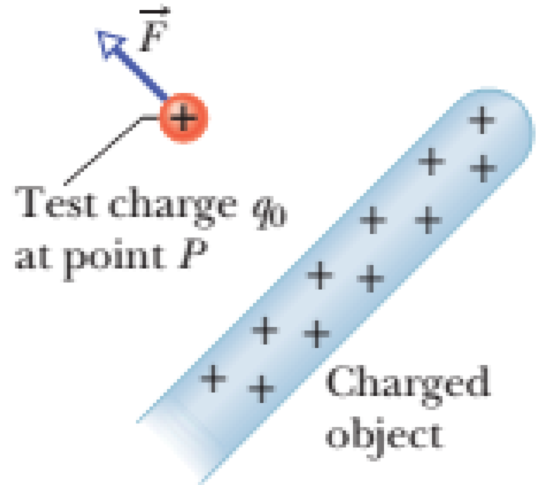
LESSON 1

BOOK CHAPTER 22

ELECTRIC FIELDS

Electric Fields

An electric field is a vector field because it is responsible for conveying the information for a force, which involves both magnitude and direction. This field consists of a distribution of electric field vectors $\vec{E}$, one for each point in the space around a charged object.



(a)

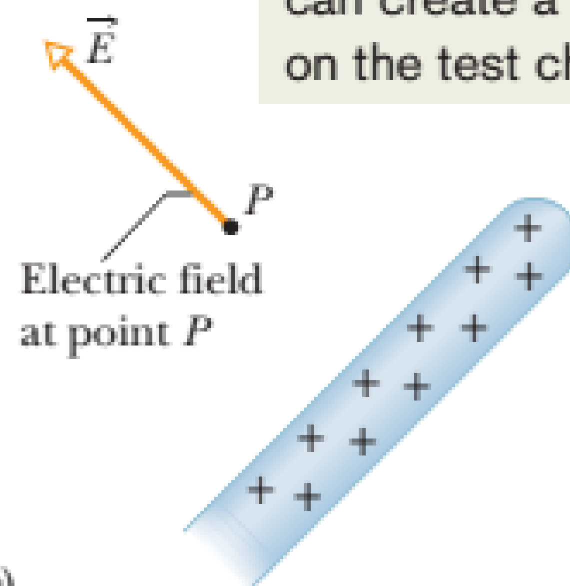
We define the electric field $\vec{E}$ at a point as the electric force $\vec{F}$ experienced by a test charge q_0 at the point, divided by the charge q_0.That is, *the electric field at a certain point is equal to the electric force per unit charge experienced by a charge at that point:*

Type equation here.

$A = \pi r^2$

$$\vec{E} = \frac{\vec{F}}{q_0}$$

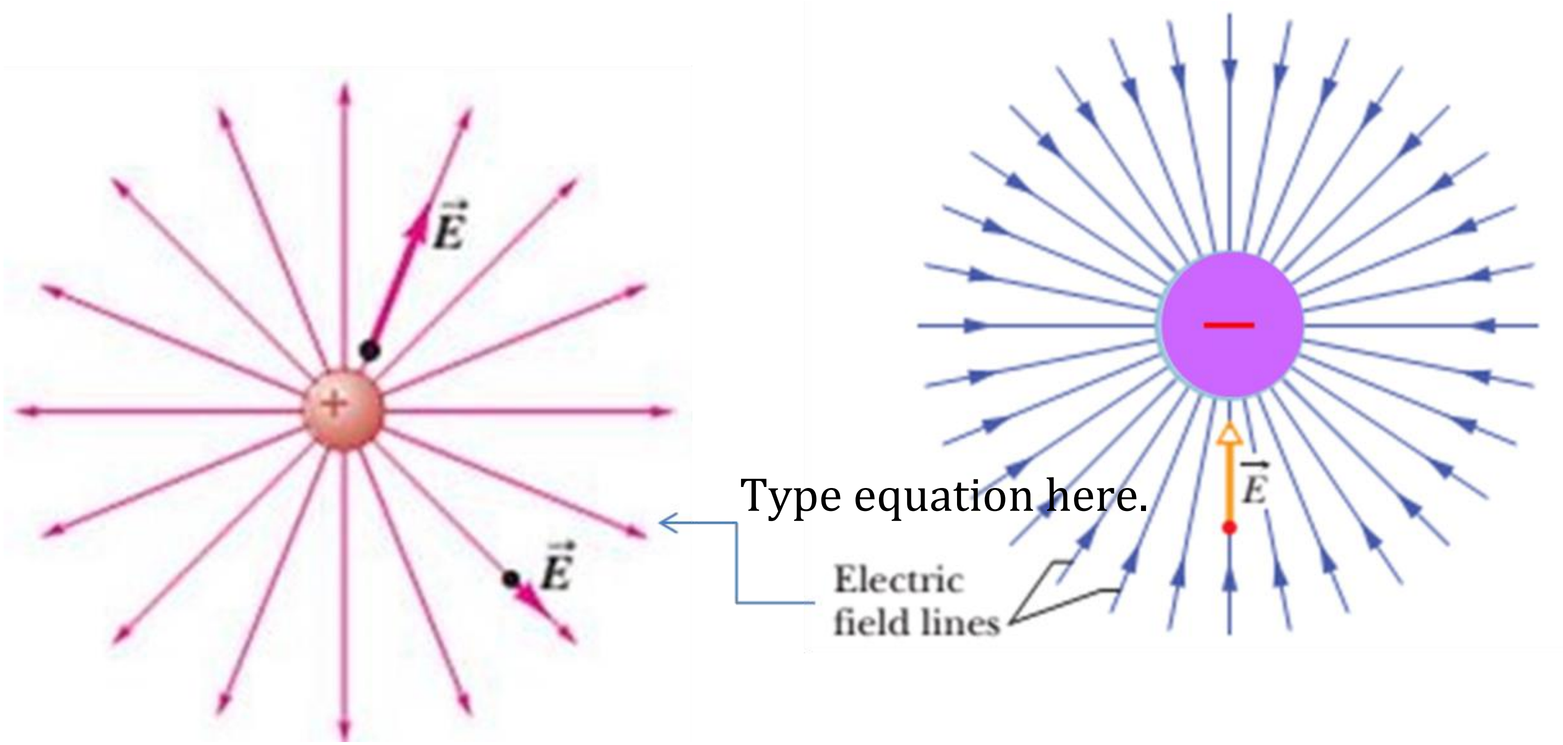
The rod sets up an electric field, which can create a force on the test charge.



(b)

The SI unit for the electric field is the Newton per Coulomb (N/C).

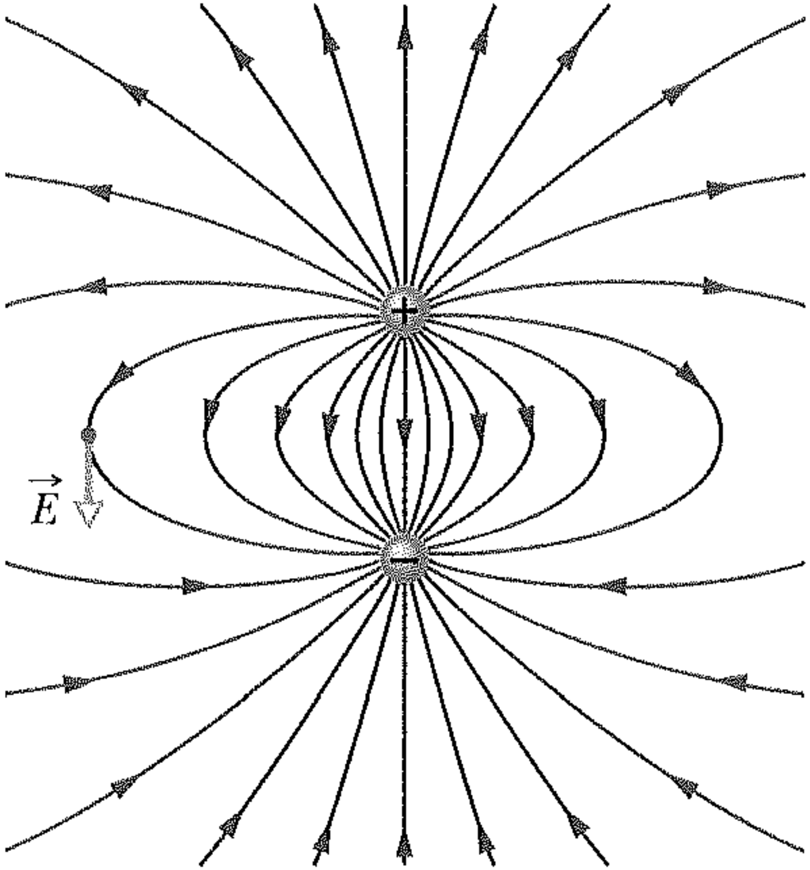
Electric Field lines around charged particles (Point Charges):



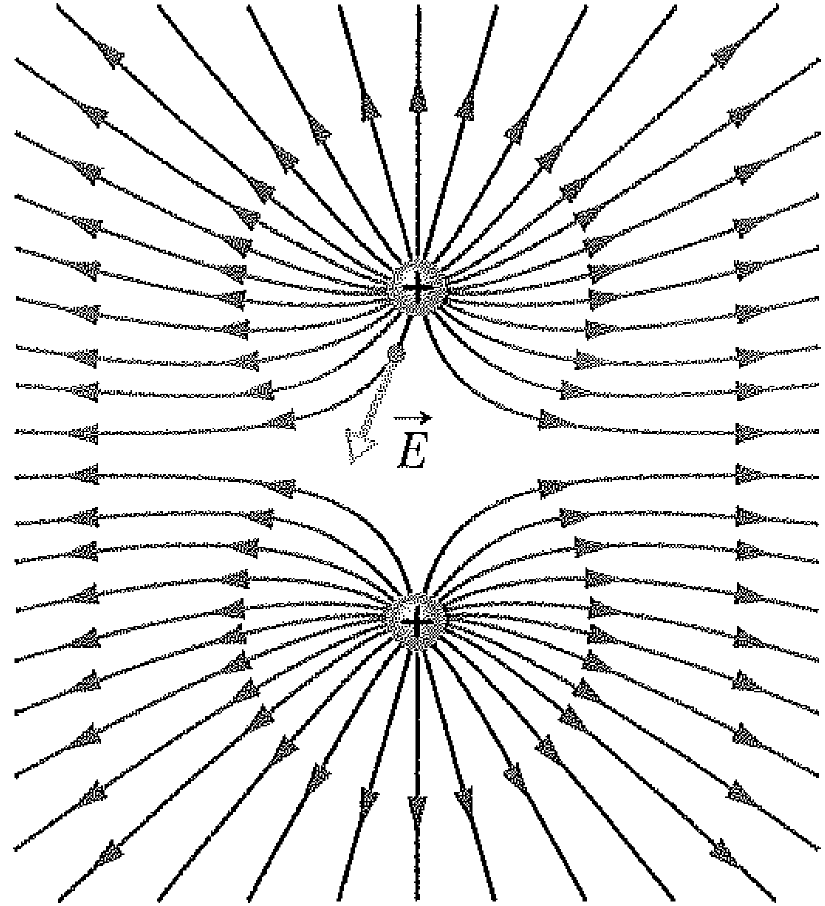
The field produced by a positive point charge points away from the charge

The field produced by a negative point charge points toward the charge

Note: Electric field lines extend away from positive charge (where they originate) and toward negative charge (where they terminate).



Field lines for a positive point charge and a nearby negative point charge that are equal in magnitude.

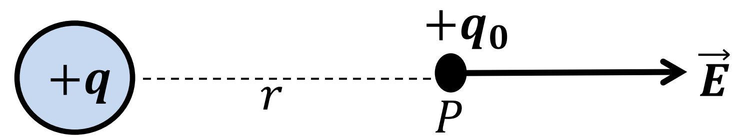


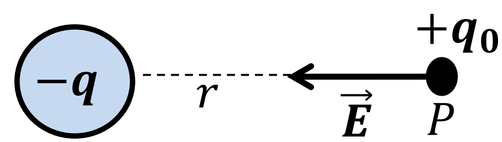
Field lines for two equal positive point charges.

Note: *Electric field lines help us visualize the direction and magnitude of electric fields.* ***The electric field vector at any point is tangent to the field line through that point. The density of field lines in that region is proportional to the magnitude of the electric field there. Thus, closer field lines represent a stronger field.***

Electric Field due to a Point Charge:

If we place a small test charge $+q_0$ at the field point P at a distance r from the point charge q, the magnitude F of the force is given by the Coulomb's law,

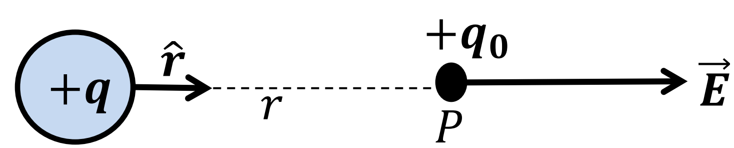


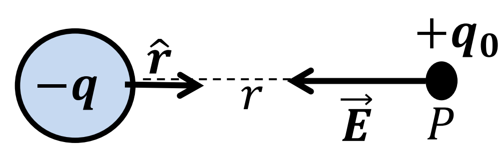


$$F = \frac{1}{4\pi\varepsilon_0}\frac{|qq_0|}{r^2}$$

The quantity $\boldsymbol{\varepsilon_0}$, called the **permittivity constant. The value of $\boldsymbol{\varepsilon_0}$ is**

$$\varepsilon_0 = 8.85 \times 10^{-12}\ \frac{C^2}{N.m^2}$$





The magnitude E of the electric field at point P is

$$E = \frac{F}{q_0} = \frac{\frac{1}{4\pi\varepsilon_0}\frac{|qq_0|}{r^2}}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

$$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}}$$

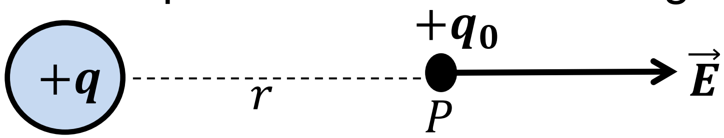
In vector form,

$$\boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}}$$

Problem 5 (Book chapter 22)

A charged particle produces an electric field with a magnitude of 2.0 N/C at a point that is 50 cm away from the particle. What is the magnitude of the particle's charge?

Answer:



Required formula:

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

$$2 = 9 \times 10^9 \frac{q}{(0.50)^2}$$

$$\boxed{q = \frac{(2)(0.25)}{9 \times 10^9} = 0.0555 \times 10^{-9}\ C}$$

Given

$E = 2.0\ N/C$

$r = 50\ cm = 0.50\ m$

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ N.m^2/C^2$

$q = ?$

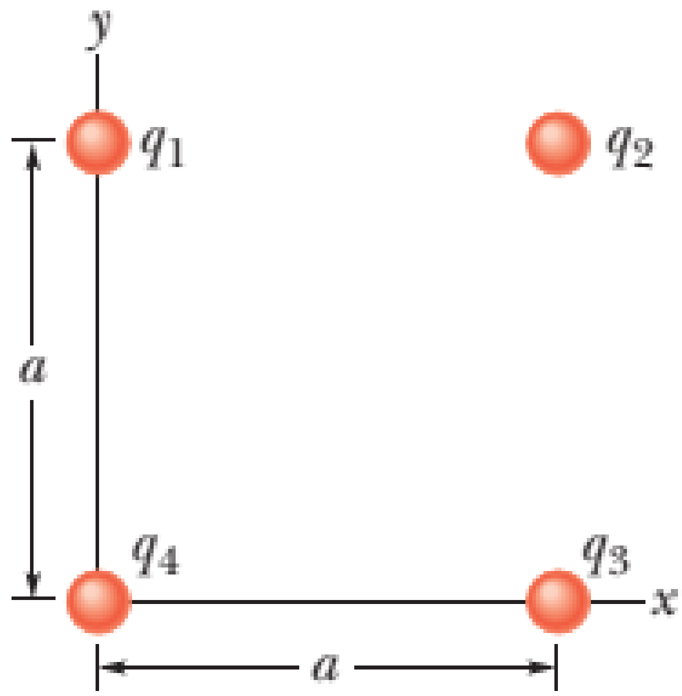
Problem 6 (Book chapter 22)

What is the magnitude of a point charge that would create an electric field of 1.00 N/C at points 1.00 m away?

Answer: Follow exactly similar steps to the answer of problem 5.

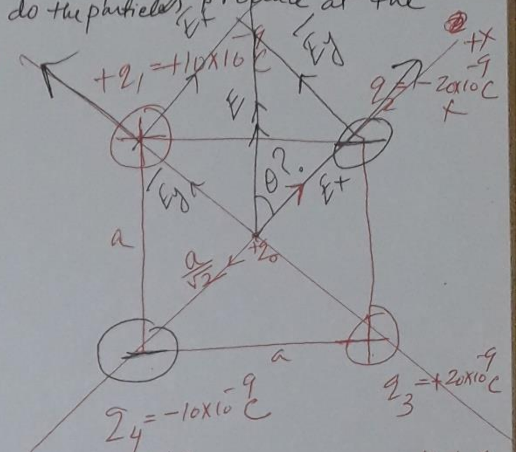
Problem 7 (Book chapter 22)

In the adjacent figure, the four particles form a square of edge length *a* = 5.00 cm and have charges $q_1 = +10\,nC$, $q_2 = -20\,nC$, $q_3 = +20\,nC$, and $q_4 = -10\,nC$. In unit-vector notation, what net electric field do the particles produce at the square's center?



13P (3) 6th (4th) New

In Fig. 22-30, the four particles form a square of edge length $a = 5.00$ cm and have charges $q_1 = +10.0$ nC, $q_2 = -20.0$ nC, $q_3 = +20.0$ nC and $q_4 = -10.0$ nC. In unit-vector notation, what net electric field do the particles produce at the square's center?



Soln

$a = 5$ cm $= 0.05$ m

~~$= 0.50$ m~~

x-axis:

$$E_x = -K\frac{|q_4|}{\left(\frac{a}{\sqrt{2}}\right)^2}\hat{i} + K\frac{|q_2|}{\left(\frac{a}{\sqrt{2}}\right)^2}\hat{i}$$

$$= -\frac{K|q_4|}{\frac{a^2}{2}} + \frac{K|q_2|}{\frac{a^2}{2}}\hat{i}$$

$$= \frac{-2K|q_4|}{a^2} + \frac{2K|q_2|}{a^2}\hat{i}$$

$$= \frac{2K}{a^2}\left[|q_2| - |q_4|\right]\hat{i}$$

$$= \frac{2\times9\times10^9}{(0.50)^2}\left(20\times10^{-9} - 10\times10^{-9}\right)\hat{i}$$

$$= \frac{2\times9\times\cancel{10^9}\times\cancel{10^{-9}}(20-10)}{(0.50)^2}\hat{i}$$

$$= \frac{2\times9\times10}{(0.50)^2}\hat{i}$$

$$= \frac{180}{0.0025}\hat{i}$$

$$E_x = 72000 \text{ N/C}\ \hat{i}$$

$$\boxed{\therefore E_x = E_y}$$

y-axis:

$$E_y = K\frac{|q_1|}{\left(\frac{a}{\sqrt{2}}\right)^2}(-\hat{j}) + K\frac{|q_3|}{\left(\frac{a}{\sqrt{2}}\right)^2}\hat{j}$$

$$= -\frac{2K|q_1|}{a^2}\hat{j} + \frac{2K|q_3|}{a^2}\hat{j}$$

$$= \frac{2K}{a^2}\left(|q_3| - |q_1|\right)\hat{j}$$

$$= \frac{2\times9\times10^9}{(0.50)^2}\left(20\times10^{-9} - 10\times10^{-9}\right)\hat{j}$$

$$= \frac{2\times9\times\cancel{10^9}\times\cancel{10^{-9}}(20-10)}{0.0025}\hat{j}$$

$$= \frac{2\times9\times10}{0.0025}\hat{j}$$

$$E_y = 72000 \text{ N/C}\ \hat{j}$$

$$\tan\theta = \left(\frac{E_y}{E_x}\right) = 1$$

$$\theta = \tan^{-1}(1)$$

$$\theta = 45^\circ \quad \text{Ans.}$$

$$E = \sqrt{E_x^2 + E_y^2}$$

$$= \sqrt{2E_x^2} = \sqrt{2(7200)^2}$$

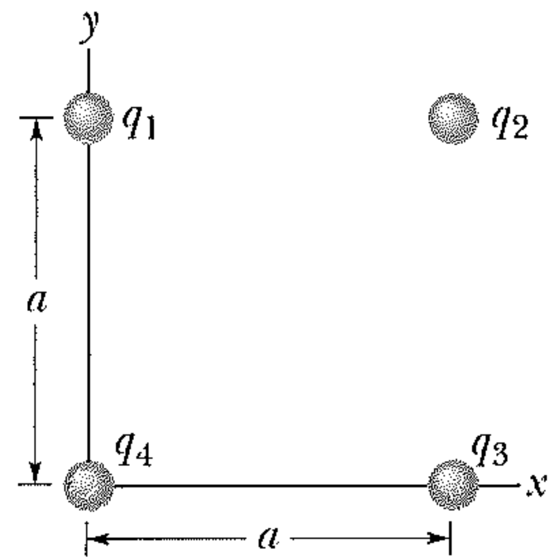
$$= \sqrt{\cancel{1036800}}$$

$$= 1,018,23.38 \text{ N/C}$$

$$E = 1.02\times10^5 \text{ N/C} \quad \text{Ans.}$$

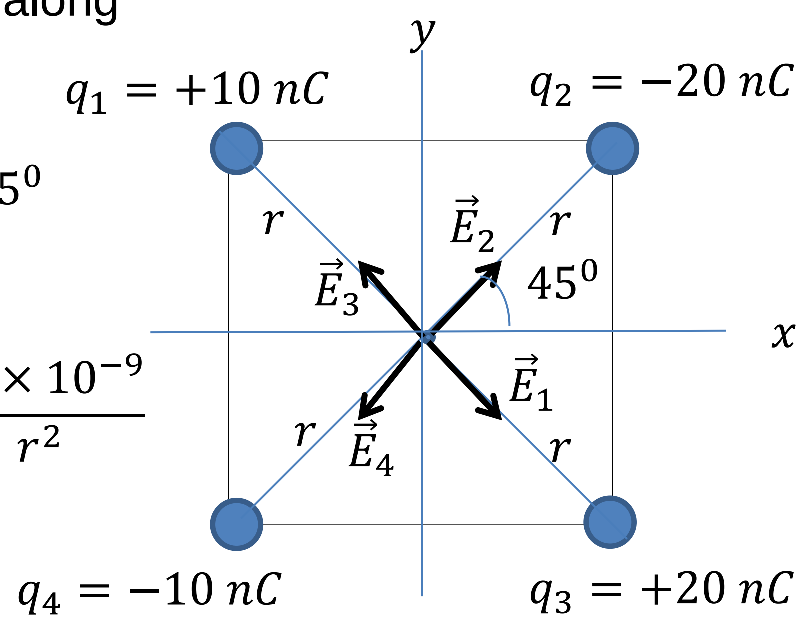
Problem 7 (Book chapter 22)

In the adjacent figure, the four particles form a square of edge length *a* = 5.00 cm and have charges $q_1 = +10\ nC$, $q_2 = -20\ nC$, $q_3 = +20\ nC$, and $q_4 = -10\ nC$. In unit-vector notation, what net electric field do the particles produce at the square's center?



Answer:

The net electric field at the center of the square along x-axis is



$$E_x = E_2 cos45^0 + E_1 cos45^0 - E_3 cos45^0 - E_4 cos45^0$$

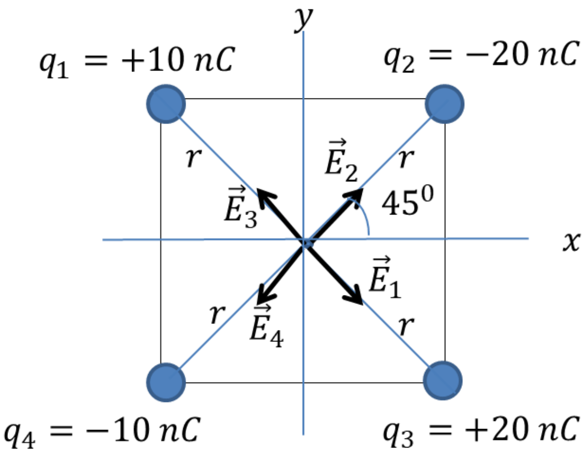
Here,

$$E_1 = E_4 = \frac{1}{4\pi\varepsilon_0}\frac{10\times10^{-9}}{r^2} \text{And} \quad E_3 = E_2 = \frac{1}{4\pi\varepsilon_0}\frac{20\times10^{-9}}{r^2}$$

$$E_x = E_2 cos45^0 + E_1 cos45^0 - E_2 cos45^0 - E_1 cos45^0$$

E_x =0 N/C

The net electric field at the center of the square along y-axis is



$$E_y = E_2 sin45^0 + E_3 sin45^0 - E_1 sin45^0 - E_4 sin45^0$$

$$E_y = E_2 sin45^0 + E_2 sin45^0 - E_1 sin45^0 - E_1 sin45^0$$

$$E_y = 2E_2 sin45^0 - 2E_1 sin45^0$$

$$E_y = \frac{2 \times 9 \times 10^9 \times 20 \times 10^{-9} \times 0.707}{r^2} - \frac{2 \times 9 \times 10^9 \times 10 \times 10^{-9} \times 0.707}{r^2}$$

$$r = \sqrt{\frac{a^2}{4} + \frac{a^2}{4}} = \sqrt{\frac{2a^2}{4}}$$

$$r = \frac{a}{\sqrt{2}} = \frac{0.05}{1.414} = 0.0354\,m$$

$$E_y = \frac{127.26}{r^2} = \frac{127.26}{(0.0354)^2} = 101.55 \times 10^3\,N/C$$

$$\vec{E} = E_x \hat{\imath} + E_y \hat{\jmath} = 0 + 101.55 \times 10^3\,\hat{\jmath} = 101.55 \times 10^3\,\hat{\jmath}\ \ \frac{N}{C}$$