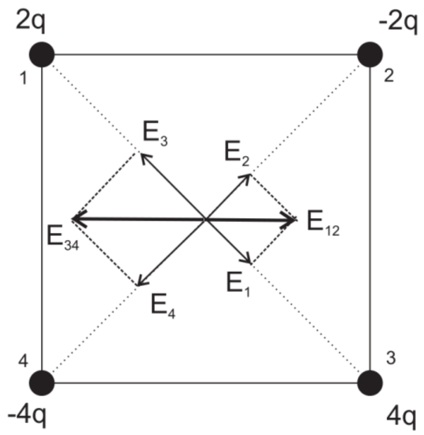
Answer on Question #85458- Physics / Electromagnetism

Question: *Four particles carrying charges + 2q, − 2q, + 4q and − 4q (with q = 1.0 nC) are kept at the vertices of a square of side 6.0 cm. Determine the net electric field due to these charged particles at the centre of the square. What is the electrostatic force on a particle carrying positive charge of 1.0 nC placed at the centre of the square?*

Answer:

Consider the following arrangement of charges as shown on the figure. The vectors of electric fields produced by them independently in the center of the square have orientation along the diagonals of the square. The net electric field can be obtained by using the superposition principle as the vector sum of these values.



The absolute values of the electric fields produced by the charges can be obtained as follows:

$$E_1 = E_2 = k\frac{2q}{(d/2)^2} \equiv E, \quad (1)$$

$$E_3 = E_4 = k\frac{4q}{(d/2)^2} = 2E, \quad (2)$$

where $d = a\sqrt{2}$ is the diagonal of the square and a is its side.

The net field of charges 1 and 2 is

$$E_{12} = \sqrt{E_1^2 + E_2^2} = E\sqrt{2} \quad (3)$$

and points horizontally right.

The net field of charges 3 and 4 is

$$E_{34} = \sqrt{E_3^2 + E_4^2} = 2E\sqrt{2} \quad (4)$$

and points horizontally left.

The total field of the four charges is just the difference between these values and points left (because $E_{34} > E_{12}$):

$$E_{tot} = E_{34} - E_{12} = E\sqrt{2} = \frac{4\sqrt{2}kq}{a^2}. \quad (5)$$

Substituting the numerical values, we obtain:

$$E_{tot} = \frac{4\sqrt{2}\cdot 9\cdot 10^9 \cdot 10^{-9}}{36\cdot 10^{-4}} \approx 1.4\cdot 10^4 \text{ V/m} \quad (6)$$

The force acting on the positive charge (that is also q as stated in the problem):

$$F = qE_{tot}. \quad (7)$$

Substituting the numerical values, we obtain:

$$F = 10^{-9}\cdot 1.4\cdot 10^4 = 1.4\cdot 10^{-5} N = 0.14 \mu N \quad (8)$$