

## CHAPTER 2

- 2.1. Three point charges are positioned in the  $x$ - $y$  plane as follows: 5nC at  $y = 5$  cm, -10 nC at  $y = -5$  cm, 15 nC at  $x = -5$  cm. Find the required  $x$ - $y$  coordinates of a 20-nC fourth charge that will produce a zero electric field at the origin.

With the charges thus configured, the electric field at the origin will be the superposition of the individual charge fields:

$$\mathbf{E}_0 = \frac{1}{4\pi\epsilon_0} \left[ \frac{15}{(5)^2} \mathbf{a}_x - \frac{5}{(5)^2} \mathbf{a}_y - \frac{10}{(5)^2} \mathbf{a}_y \right] = \frac{1}{4\pi\epsilon_0} \left( \frac{3}{5} \right) [\mathbf{a}_x - \mathbf{a}_y] \quad \text{nC/m}$$

The field,  $\mathbf{E}_{20}$ , associated with the 20-nC charge (evaluated at the origin) must exactly cancel this field, so we write:

$$\mathbf{E}_{20} = \frac{-1}{4\pi\epsilon_0} \left( \frac{3}{5} \right) [\mathbf{a}_x - \mathbf{a}_y] = \frac{-20}{4\pi\epsilon_0 \rho^2} \left( \frac{1}{\sqrt{2}} \right) [\mathbf{a}_x - \mathbf{a}_y]$$

From this, we identify the distance from the origin:  $\rho = \sqrt{100/(3\sqrt{2})} = 4.85$ . The  $x$  and  $y$  coordinates of the 20-nC charge will both be equal in magnitude to  $4.85/\sqrt{2} = 3.43$ . The coordinates of the 20-nC charge are then (3.43, -3.43).

- 2.2. Point charges of 1nC and -2nC are located at (0,0,0) and (1,1,1), respectively, in free space. Determine the vector force acting on each charge.

First, the electric field intensity associated with the 1nC charge, evaluated at the -2nC charge location is:

$$\mathbf{E}_{12} = \frac{1}{4\pi\epsilon_0(3)} \left( \frac{1}{\sqrt{3}} \right) (\mathbf{a}_x + \mathbf{a}_y + \mathbf{a}_z) \quad \text{nC/m}$$

in which the distance between charges is  $\sqrt{3}$  m. The force on the -2nC charge is then

$$\mathbf{F}_{12} = q_2 \mathbf{E}_{12} = \frac{-2}{12\sqrt{3}\pi\epsilon_0} (\mathbf{a}_x + \mathbf{a}_y + \mathbf{a}_z) = \frac{-1}{10.4\pi\epsilon_0} (\mathbf{a}_x + \mathbf{a}_y + \mathbf{a}_z) \quad \text{nN}$$

The force on the 1nC charge at the origin is just the opposite of this result, or

$$\mathbf{F}_{21} = \frac{+1}{10.4\pi\epsilon_0} (\mathbf{a}_x + \mathbf{a}_y + \mathbf{a}_z) \quad \text{nN}$$

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**M Woodhall**



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