Electric Forces and Fields

Problem B

THE SUPERPOSITION PRINCIPLE

PROBLEM

Consider three point charges on the *x*-axis: $q_1 = 4.92 \times 10^{-9}$ C is at the origin, $q_2 = -6.99 \times 10^{-8}$ C is at $x = -3.60 \times 10^{-1}$ m, and $q_3 = 5.65 \times 10^{-9}$ C is at $x = 1.44$ m. Find the magnitude and direction of the resultant force on q_1.

SOLUTION

Given: $q_1 = 4.92 \times 10^{-9}$ C $\quad r_{1,2} = -3.60 \times 10^{-1}$ m

$q_2 = -6.99 \times 10^{-8}$ C $\quad r_{1,3} = 1.44$ m

$q_3 = 5.65 \times 10^{-9}$ C $\quad k_C = 8.99 \times 10^9$ N•m²/C²

Unknown: $F_{1,tot} = ?$

Calculate the magnitude of the forces with Coulomb's law:

$$F_{1,2} = \frac{k_C q_1 q_2}{r_{1,2}^{\ 2}} = \frac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(4.92 \times 10^{-9}\text{ C})(-6.99 \times 10^{-8}\text{ C})}{(-3.60 \times 10^{-1}\text{ m})^2} = -2.39 \times 10^{-5}\text{ N}$$

$$F_{1,3} = \frac{k_C q_1 q_3}{r_{1,3}^{\ 2}} = \frac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(4.92 \times 10^{-9}\text{ C})(5.65 \times 10^{-9}\text{ C})}{(1.44\text{ m})^2} = 1.21 \times 10^{-5}\text{ N}$$

The forces are all along the *x*-axis, so add up the *x*-components:

$$F_{1,tot} = F_{1,2} + F_{1,3} = -2.39 \times 10^{-5}\text{ N} + 1.21 \times 10^{-5}\text{ N} = \boxed{-1.18 \times 10^{-5}\text{ N}}$$

ADDITIONAL PRACTICE

1. Suppose four protons were at the corners of a square. The length of each side of the square is 1.52×10^{-9} m. If q_1 is on the upper right corner, calculate the magnitude and direction of the resultant force on q_1.

2. Consider three point charges, $q_1 = 4.50$ C, $q_2 = 4.50$ C, and $q_3 = 6.30$ C, located at the corners of an isosceles triangle. The charges q_1 and q_2 are 5.00 m apart and form the base. The triangle is 3.50 m high, and q_3 is located at the top. Calculate the magnitude and direction of the resultant force on q_3.

3. Imagine three point charges on the corners of a triangle: $q_1 = -9.00$ nC is at the origin, $q_2 = -8.00$ nC is at $x = 2.00$ m, and $q_3 = 7.00$ nC is at $y = 3.00$ m. Find the magnitude and direction of the resultant force on q_1.

4. Suppose three point charges are on the *y*-axis: $q_1 = -2.34 \times 10^{-8}$ C is at the origin, $q_2 = 4.65 \times 10^{-9}$ C is at $y = 0.500$ m, and $q_3 = -2.99 \times 10^{-10}$ C is at $y = 1.00$ m. What is the magnitude and direction of the resultant force on q_1?

5. Consider four electrons at the corners of a square. Each side of the square is 3.02×10^{-5} m. Find the magnitude and direction of the resultant force on q_3 if it is at the origin.

6. Imagine three point charges at the corners of an isosceles triangle: $q_1 = 2.22 \times 10^{-10}$ C, $q_2 = 3.33 \times 10^{-9}$ C, and $q_3 = 4.44 \times 10^{-8}$ C. The charges q_1 and q_2 are 1.00 m apart and form the triangle's base. The triangle is 0.250 m tall. If q_3 is at the top, what is the magnitude and direction of the resultant force on q_3?

7. Consider three 2.0 nC point charges at the following locations: at (0 m, 0 m), at (1.0 m, 2.0 m), and at (1.0 m, 0 m). Find the magnitude and direction of the resultant force on the charge at the origin.

8. Consider three point charges on the corners of a triangle, where $q_1 = -4.0$ mC at the origin; $q_2 = -8.0$ mC at (2.0 m, 0 m); and $q_3 = 2.0$ mC at (0 m, 2.0 m). Calculate the magnitude and direction of the resultant force on q_1.

9. Suppose three point charges are on the corners of a triangle: $q_1 = 9.00$ mC is at the origin, $q_2 = 6.00$ mC is at the point (1.00 m, 1.00 m), and $q_3 = 3.00$ mC is at (–1.00 m, 1.00 m). Find the magnitude and direction of the resultant force on q_1.

10. Consider three equal point charges of 4.00 nC on a line. All charges are 4.00 m apart. Calculate the magnitude and direction of the resultant force on the charge in the middle.