

University Physics with Modern Physics

Electromagnetism Problems

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21 Electric Charge and Electric Field

21.3 Coulomb's Law

21.3.1 Example 21.1

The magnitude of electric repulsion between two α particles is given by

$$F_e = \frac{1}{4\pi\epsilon_0} \frac{q^2}{r^2}$$

and the magnitude of gravitational attraction is given by

$$F_g = \frac{Gm^2}{r^2}$$

. The ratio of the two values is

$$\begin{aligned} \frac{F_e}{F_g} &= \frac{1}{4\pi\epsilon_0} \frac{q^2}{r^2} \frac{r^2}{Gm^2} \\ &= \frac{1}{4\pi\epsilon_0} \frac{q^2}{Gm^2} \\ &= 3.1 \times 10^{35} \end{aligned}$$

showing that the electric repulsion is significantly stronger than the gravitational attraction.

21.3.2 Example 21.2

a) The magnitude of the force that q_1 exerts on q_2 is

$$\begin{aligned} F &= \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \\ &= (9.0 \times 10^9) \frac{|(25 \times 10^{-9})(-75 \times 10^{-9})|}{0.030^2} \\ &= 1.9 \times 10^{-2} \text{ N.} \end{aligned}$$

Since q_1 and q_2 have opposite charge, the force is attractive (from q_2 to q_1).

b) The magnitude of the force that q_2 exerts on q_1 is the same as in part a, but the direction is reversed (from q_1 to q_2).

21.3.3 Example 21.3

By the principle of superposition of forces, the net force exerted on q_3 is equal to the vector sum of the forces exerted on it by q_1 and q_2 separately.

Both q_1 and q_3 have positive charge so they repel each other. q_1 is to the right of q_3 so q_3 experiences a force to the left of magnitude

$$\begin{aligned} F_{1 \text{ on } 3} &= \frac{1}{4\pi\epsilon_0} \frac{|q_1 q_3|}{r^2} \\ &= (9.0 \times 10^9) \frac{|(1.0 \times 10^{-9})(5.0 \times 10^{-9})|}{0.020^2} \\ &= 1.1 \times 10^{-4} \text{ N.} \end{aligned}$$

However q_2 has a negative charge so it attracts q_3 . It is also to the right of q_3 so q_3 experiences a force to the right of magnitude

$$\begin{aligned} F_{2 \text{ on } 3} &= \frac{1}{4\pi\epsilon_0} \frac{|q_2 q_3|}{r^2} \\ &= (9.0 \times 10^9) \frac{|(-3.0 \times 10^{-9})(5.0 \times 10^{-9})|}{0.040^2} \\ &= 8.4 \times 10^{-5} \text{ N.} \end{aligned}$$

The net force experienced by q_3 is therefore

$$\begin{aligned} F &= -F_{1 \text{ on } 3} + F_{2 \text{ on } 3} \\ &= -1.1 \times 10^{-4} + 8.4 \times 10^{-5} \\ &= -2.6 \times 10^{-5} \text{ N.} \end{aligned}$$

21.3.4 Example 21.4

Since q_1 and q_2 are of equal charge and are symmetric about the x axis on which Q lies, the vertical components of their forces cancel leaving only the horizontal.

The horizontal component of q_1 's force on Q is given by

$$\begin{aligned} F_{1 \text{ on } Q, x} &= \frac{1}{4\pi\epsilon_0} \frac{q_1 Q}{r_{1,Q}^2} \cos \alpha \\ &= (9.0 \times 10^9) \frac{(2.0 \times 10^{-6})(4.0 \times 10^{-6})}{\sqrt{0.30^2 + 0.40^2}} \frac{0.40}{0.50} \\ &= 0.23 \text{ N.} \end{aligned}$$

Again, since q_1 and q_2 are of equal charge and symmetric about the x axis, $F_{1 \text{ on } Q, x} = F_{2 \text{ on } Q, x}$ and the total force experienced by Q is in the positive x direction of magnitude

$$F = 2F_{1 \text{ on } Q, x} = 0.46 \text{ N.}$$