Problem 25.2

A plastic rod is charged to \(-20 \text{ nC}\) by rubbing.

Part A
How many electrons have been added or protons removed?

**ANSWER:**
1.25 \times 10^{11} \text{ particles}
1.25 \times 10^{11} \text{ particles}

The magnitude of the charge on an electron is

\[ e = 1.60 \times 10^{-19} \text{ C} \]

So the number of electrons or protons is

\[ n = \frac{q_1}{e} = \frac{-20 \times 10^{-9} \text{ C}}{1.60 \times 10^{-19} \text{ C}} = 1.25 \times 10^{11} \]

Problem 25.34

Two protons are 2.0 fm apart.

Part A
What is the magnitude of the electric force on one proton due to the other proton?

Use Coulomb's Law.

\[ 2 F_m = 2 \times 10^{-15} \text{ m} \]

\[
F = \frac{1}{4 \pi \varepsilon_0} \frac{q_1 q_2}{r_{12}^2}
\]

\[ |F| = \frac{1}{4 \pi \varepsilon_0} \frac{9.92^2}{1.2^2} \]

Magnitude of \( r_{12} \)

Cancels one factor in denominator

\[ F = (8.99 \times 10^9 \frac{N \text{ m}^2}{\text{C}^2}) \left( \frac{1.6 \times 10^{-19} \text{ C}}{2.0 \times 10^{-15} \text{ m}} \right)^2 = 5.75 \text{ N} \]

Part B
What is the magnitude of the gravitational force on one proton due to the other proton?

For Gravity:

\[ F = G \frac{m_1 m_2}{r_{12}^2} = (6.67 \times 10^{-11} \frac{\text{N} \text{ m}^2}{\text{kg}^2}) \left( \frac{1.673 \times 10^{-27} \text{ kg}}{(2.0 \times 10^{-15} \text{ m})^2} \right) = 4.67 \times 10^{-35} \text{ N} \]

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Problem 25.34 (cont.)

Part C

What is the ratio of the electric force to the gravitational force?

The ratio is \[ \frac{57.5}{4.67 \times 10^{-35}} = 1.23 \times 10^{36} \]

Magnitude and Direction of Electric Fields

Description: Short quantitative problem for which students must find the charge producing an electric field and sum the electric fields produced by two charges. This problem is based on Young/Geller Conceptual Analysis 17.6.

A small object A, electrically charged, creates an electric field. At a point P located 0.250 m directly north of A, the field has a value of 40.0 N/C directed to the south.

Part A

What is the charge of object A?

The electric field can be written: (Note \( \frac{q}{r^3} = \frac{\lambda}{r^2} \))

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

Take magnitude & solve for \( q \):

\[ q = 4 \pi \varepsilon_0 E r^2 = \frac{40 \text{ N/C} (0.250 \text{ m})^2}{8.99 \times 10^9 \text{ Nm}^2/\text{C}^2} \]

\[ = -2.78 \times 10^{-10} \text{ C} \quad \text{(Negative sign)} \]

Part B

If a second object B with the same charge as A is placed at 0.250 m south of A (so that objects A and B and point P follow a straight line), what is the magnitude of the total electric field produced by the two objects at P?

\[ \vec{E}_B = \frac{1}{4 \pi \varepsilon_0} \frac{\lambda}{r^3} \vec{r} = \left(8.99 \times 10^9 \text{ Nm}^2/\text{C}^2\right) \left(\frac{-2.78 \times 10^{-10} \text{ C}}{(0.5 \text{ m})^3}\right)(40.5 \text{ m} \uparrow) \]

\[ = -10.0 \text{ N/C} \quad \text{(Note this is } \frac{1}{4} \text{ of } \vec{E}_A) \]

\[ \vec{E}_\text{total} = \vec{E}_A + \vec{E}_B = -40 \uparrow \text{ N/C} - 10 \uparrow \text{ N/C} = -50 \uparrow \text{ N/C} \]

\[ E_\text{total} = 50 \text{ N/C} \]

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Problem 25.12

Two small plastic spheres each have a mass of 1.50 g and a charge of $-53.0 \, \text{nC}$. They are placed 3.00 cm apart.

Part A

What is the magnitude of the electric force between the spheres?

$$F = \frac{1}{4\pi \varepsilon_0} \frac{|q_1 q_2|}{r_{12}^2} = \left(8.99 \times 10^{-9} \, \frac{N m^2}{C^2}\right) \frac{(53 \times 10^{-9} \, C)^2}{(3.0 \times 10^{-2} \, m)^2}$$

$$= 2.81 \times 10^{-2} \, \text{N}$$

Part B

By what factor is the electric force on a sphere larger than its weight?

$$w = mg = (1.50 \times 10^{-3} \, \text{kg}) (9.807 \, \frac{\text{kg} \, \text{m}}{\text{s}^2})$$

$$= 1.47 \times 10^{-2} \, \text{N}$$

$$\text{Ratio} = \frac{F_e}{w} = \frac{2.81 \times 10^{-2} \, \text{N}}{1.47 \times 10^{-2} \, \text{N}} = 1.91$$