PHYSICS IN MOTION
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# Unit 5C
# Coulomb's Law
# *Practice Problems TEACHER*

**Work each of the following problems. SHOW ALL WORK.**

1. **A lightning bolt transfers 22 C of charge to the earth. How many electrons are transferred from this one bolt? The earth is struck by an average of 100 lightning bolts each second. How many electrons pour into the earth each second from lightning?**

*The charge magnitude of a single electron is $1.6 \times 10^{-19}$ C.*

*The number of electrons transferred through a single bolt is:*

$$\frac{22\,C}{1.6 \times 10^{-19}\,C} = 1.4 \times 10^{20}$$

*Multiply this result by 100 to determine the average number of electrons transferred to the earth in one second ($1.4 \times 10^{22}$).*

2. **How far apart are two protons if they exert a force of 0.5 N on each other?**

$$F_{electric} = \frac{k|q_1 q_2|}{r^2}$$

$$r = \sqrt{\frac{k|q_1 q_2|}{F}}$$

$$k = 9 \times 10^9\ Nm^2/C^2$$
$$q_1 = 1.6 \times 10^{-19}\,C$$
$$q_2 = 1.6 \times 10^{-19}\,C$$
$$F_{electric} = 0.5\,N$$

$$r = \sqrt{\frac{(9 \times 10^9\ Nm^2/C^2)|(1.6 \times 10^{-19}\,C)(1.6 \times 10^{-19}\,C)|}{0.5\,N}}$$

$$r = 2.2 \times 10^{-14}\,m$$

3. **Two electrons in bulk matter are an angstrom ($1 \times 10^{-10}$ m) apart. What electrostatic force do they exert on each other?**

$$F_{electric} = \frac{k|q_1 q_2|}{r^2}$$

$$k = 9 \times 10^9\ Nm^2/C^2$$
$$q_1 = 1.6 \times 10^{-19}\,C$$
$$q_2 = 1.6 \times 10^{-19}\,C$$
$$r = 1 \times 10^{-10}\,m$$

$$F_{electric} = \frac{(9.0 \times 10^9\ Nm^2/C^2)|(-1.6 \times 10^{-19}\,C)(-1.6 \times 10^{-19}\,C)|}{(1 \times 10^{-10}\,m)^2}$$

$$F_{electric} = 2.3 \times 10^{-8}\,N$$

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**Work each of the following problems. SHOW ALL WORK.**

4. **One point charge has a magnitude of 5.4 x 10^-7^ C. A second charge that is 0.25 m away has a magnitude of 1.1 x 10^-17^ C. What is the electric force magnitude of one charge on the other?**

$$F_{electric} = \frac{k|q_1 q_2|}{r^2}$$

$$k = 9 \times 10^9\ Nm^2/C^2$$
$$q_1 = 5.4 \times 10^{-7}\ C$$
$$q_2 = 1.1 \times 10^{-17}\ C$$
$$r = 0.25\ m$$

$$F_{electric} = \frac{(9 \times 10^9\ Nm^2/C^2)|(5.4 \times 10^{-7}\ C)(1.1 \times 10^{-17}\ C)|}{(0.25\ m)^2}$$
$$F_{electric} = 8.6 \times 10^{-13}\ N$$

5. **A piece of styrofoam has a charge of 0.002 mC and is placed 0.5 m from a grain of salt with a charge of 0.03 nC. How much electrostatic force is produced?**

$$F_{electric} = \frac{k|q_1 q_2|}{r^2}$$

$$k = 9 \times 10^9\ Nm^2/C^2$$
$$q_1 = 0.002\ mC = 2 \times 10^{-6}\ C$$
$$q_2 = 0.03\ nC = 3 \times 10^{-11}\ C$$
$$r = 0.5\ m$$

$$F_{electric} = \frac{(9.0 \times 10^9\ Nm^2/C^2)|(2 \times 10^{-6}\ C)(3 \times 10^{-11}\ C)|}{(0.5\ m)^2}$$
$$F_{electric} = 2.2 \times 10^{-6}\ N$$

6. **A charged object has 82 protons, 82 neutrons, and 109 electrons. What is its overall charge? (Be sure to include the sign.)**

*The neutrons have no charge. The charges of the protons and the electrons are equal and opposite, so 82 charges cancel one another out, leaving 27 electron charges, each with a value of $-1.6 \times 10^{-19}$ C.*

$$(-1.6 \times 10^{-19}\ C)(27) = -4.3 \times 10^{-18}\ C$$

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**Work each of the following problems. SHOW ALL WORK.**

7. **In order to collect weather data on a remote island, you decide to send a weather balloon to the location. You attach a 1 C charged object to the balloon and plan to propel it to the island using electrostatic force. Given the balloon's size and the standard wind patterns en route, you will need to overcome an opposing air resistance of up to 100 N at any point on the balloon's journey. How much charge will you need to propel the 1 C balloon from your location to the island 750 km away, considering the opposing wind? Ignore the curvature of the earth.**

*You will need to exert an electrostatic force of 100 N on the weather balloon considering a maximum distance of 750 km. Rearrange Coulomb's law to solve for $q_2$, the charge needed from the starting location:*

$$F_{electric} = \frac{k|q_1 q_2|}{r^2}$$

$$|q_2| = \frac{Fr^2}{k|q_1|}$$

$$F_{electric} = 100\,N$$
$$k = 9 \times 10^9\,Nm^2/C^2$$
$$r = 750\,km = 750{,}000\,m$$
$$q_1 = 1C$$

$$|q_2| = \frac{(100\,N)(750{,}000\,m)^2}{(9 \times 10^9\,Nm^2/C^2)|(1\,C)|}$$
$$q_2 = 6.3 \times 10^3\,C$$

8. **A metal sphere with a charge of 2.3 x 10$^{-6}$ C lies 2 m away from another metal sphere of unknown charge. If the attractive force between the spheres is 0.05 N, what is the charge of the second sphere?**

$$F_{electric} = \frac{k|q_1 q_2|}{r^2}$$

$$|q_2| = \frac{Fr^2}{k|q_1|}$$

$$F_{electric} = 0.05\,N$$
$$k = 9 \times 10^9\,Nm^2/C^2$$
$$r = 2\,m$$
$$q_1 = 2.3 \times 10^{-6}\,C$$

$$|q_2| = \frac{(0.05\,N)(2\,m)^2}{(9 \times 10^9\,Nm^2/C^2)|(2.3 \times 10^{-6}\,C)|}$$
$$q_2 = 9.7 \times 10^{-6}\,C$$

*Given that the force between the charges is attractive, we know $q_2$ is negatively charged.*

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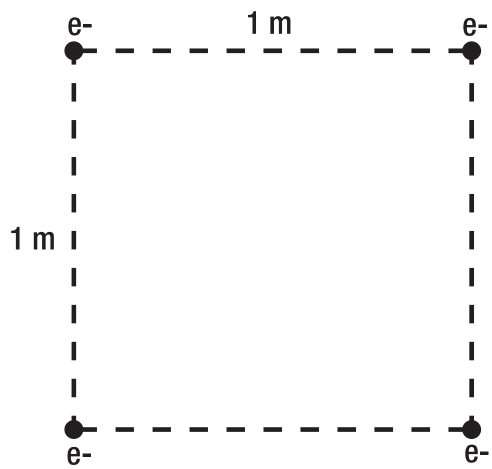
**Work each of the following problems. SHOW ALL WORK.**

**9. Four electrons are each located on the corners of a square, with the sides of the square measuring 1 m long. What is the total force (magnitude and direction) exerted on one of the electrons by the other three?**

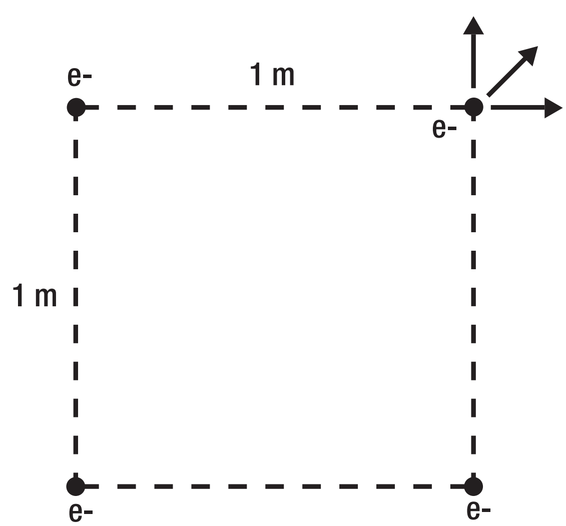
*Use Coulomb's law to determine the force magnitude,*

*and visualize the situation to determine the force direction.*




*Choose any corner as the focus. Considering the electron at the top right corner,*

*the force direction from the other three electrons can be drawn as below:*

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**Work each of the following problems. SHOW ALL WORK.**

*The distance between the top right electron and either adjacent electron is 1 m. The distance between the top right electron and the bottom left electron is $\sqrt{2}$ m, considering a 45°, 45°, 90° triangle with sides of length 1 m. The force magnitude between the top right and either adjacent electron is:*

$$F_{adj} = \frac{k|q_e q_e|}{r_{adj}^2}$$

$$F_{adj} = \frac{(9 \times 10^9\ Nm^2/C^2)|(-1.6 \times 10^{-19}\ C)(-1.6 \times 10^{-19}\ C)|}{(1m)^2}$$

$$F_{adj} = 2.3 \times 10^{-28}\ N$$

*The force magnitude between the top right and bottom left electron is:*

$$F_{diag} = \frac{k|q_e q_e|}{r_{diag}^2}$$

$$F_{diag} = \frac{(9 \times 10^9\ Nm^2/C^2)|(-1.6 \times 10^{-19}\ C)(-1.6 \times 10^{-19}\ C)|}{(\sqrt{2}\,m)^2}$$

$$F_{diag} = 1.2 \times 10^{-28}\ N$$

| Forces | x-component | y-component |
|---|---|---|
| $F_{adj1} = 2.3 \times 10^{-28}$ N | $2.3 \times 10^{-28}$ N | 0 |
| $F_{adj2} = 2.3 \times 10^{-28}$ N | 0 | $2.3 \times 10^{-28}$ N |
| $F_{diag} = 1.2 \times 10^{-28}$ N | $1.2 \times 10^{-28}$ N (cos45°) = $8.5 \times 10^{-29}$ N | $1.2 \times 10^{-28}$ N (sin45°) = $8.5 \times 10^{-29}$ N |
| **Total** | $3.15 \times 10^{-28}$ N | $3.15 \times 10^{-28}$ N |

*To find the magnitude of the net force:*

$$F_{net} = \sqrt{(\Sigma x)^2 + (\Sigma y)^2}$$

$$F_{net} = \sqrt{(3.15 \times 10^{-28}\ N)^2 + (3.15 \times 10^{-28}\ N}$$

$$F_{net} = \sqrt{1.98 \times 10^{-55}\ N}$$

$$F_{net} = 4.5 \times 10^{-28}\ N$$

*To find the direction of the net force:*

$$\Theta = \tan^{-1}\left(\frac{\Sigma x}{\Sigma y}\right)$$

$$\Theta = \tan^{-1}\left(\frac{3.15 \times 10^{-28}}{3.15 \times 10^{-28}}\right)$$

$$\Theta = \tan^{-1}(1)$$

$$\Theta = 45°$$