Interactions Between Charged Particles

Why?

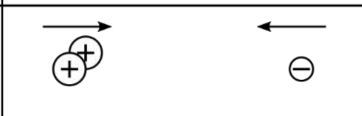
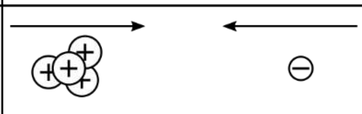
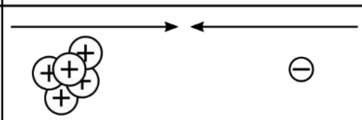
Imagine a group of people near an object. When people say, "That's so attractive," they want to move toward the object. When people say, "That's so repulsive!" they want to move away from the object. We can observe how people interact with objects in both these ways.

How do very tiny particles interact when they are near each other? Do they exhibit attraction and repulsion, too? In this activity we will explore how charged particles interact when they are near each other.

As you work through the following questions, be sure to follow your team role(s).

Model 1 – How does the amount of charge affect the force between oppositely-charged particles?

Protons interacting with one electron at a distance of 0.2 nm

Situation	Diagram of particles interacting	Amount of + charge	Force of attraction (F_e) ($\times 10^{-9}$ N)
1			5.75
2			11.5
3			17.3
4			23.0
5			28.8

Particles are not drawn to scale.
One nanometer is one billionth of a meter. Its abbreviation is nm.
One Newton is abbreviated as N.

KEY

⊕ = Proton (charge of +1)   ⊖ = Electron (charge of −1)

→ ← = Attractive force between oppositely-charged particles

Use the information in Model 1 to answer questions 1 – 10.
Reach agreement with your team before writing down your consensus answers.

1. Look carefully at Model 1. Focus on the column headings, notes, and KEY.
Write the meaning of each symbol or abbreviation used in the data table.

nm = ____________________ N = ____________________

⊕ = ____________________ ⊖ = ____________________

→ ← = ____

2. Look at the KEY in Model 1.

a. What is the charge on one electron?

b. What is the charge on one proton?

3. Look closely at the title of Model 1. **How many electrons** are interacting with protons in each situation?

4. Look closely at the headings of each column in the data table in Model 1.

a. What is the **distance** between protons and electrons in each situation?
Include the correct unit.

b. **Highlight** the row that shows one proton and one electron located 0.2 nanometers apart.

5. Count the number of protons present in each situation in Model 1. **Write the numbers** in the column labeled **Amount of + charge**.

6. Focus on the column labeled **Amount of + charge** in Model 1.
Do the numbers decrease, stay the same, or increase?

As you look from top to bottom of the column, the ***amount of positive (+) charge…***

7. Focus on the column labeled **Force of attraction i**n Model 1.
Do the numbers decrease, stay the same, or increase?

As you look from top to bottom of the column, the ***Force of Attraction*** *values…*

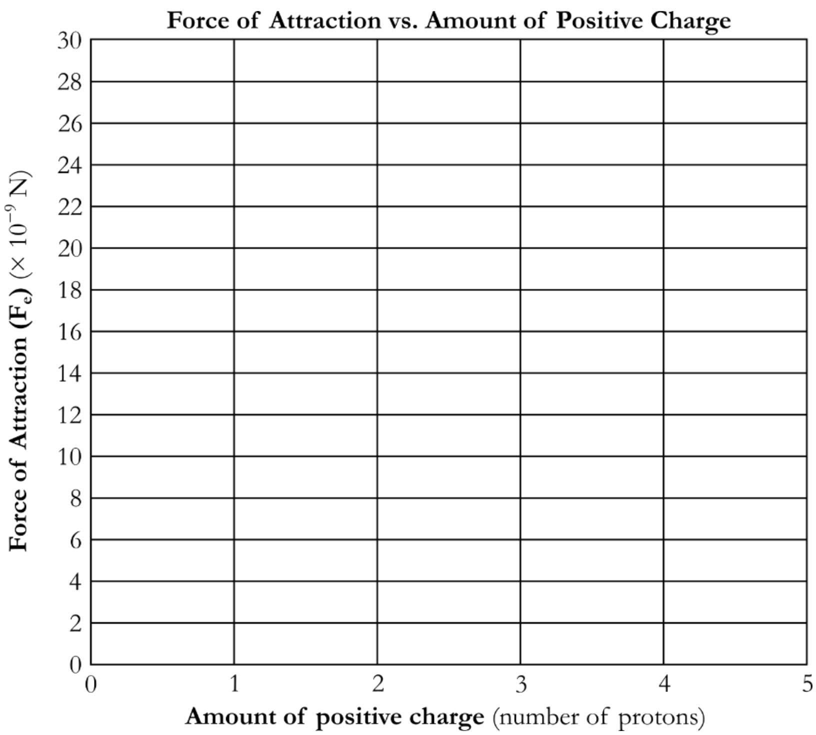
8. Write one sentence that describes the relationship between the **amount of positive (+) charge** and the **force of attraction**. Include one or more of these terms or phrases in your sentence: decreases, stays the same, increases.

Check your answer to question 8 with your teacher before you continue.

9. Use the data from Model 1 to create a graph.

    a. Plot the data from all five situations in Model 1.

    b. Draw a line of best fit (straight line or smooth curve) to connect the points you plot.



10. Circle the one statement below that best summarizes the meaning of your graph.

    a. As the amount of positive charge increases, the $\mathbf{F_e}$ increases at a steady rate (linearly).

    b. As the amount of positive charge increases, the $\mathbf{F_e}$ decreases at a steady rate (linearly).

    c. As the amount of positive charge increases, the $\mathbf{F_e}$ increases more and more quickly.

    d. As the amount of positive charge increases, the $\mathbf{F_e}$ decreases more and more slowly.

Send a spy to check your graph with two other teams before you continue.

Read This!

Physicists and chemists use the term **electrostatic force** to describe the force of attraction between charged particles (protons and electrons).

Model 2 – How does the distance between two oppositely-charged particles affect the electrostatic force between those particles?

Situation	Distance between particles (nm)	Electrostatic Force (F_e) ($\times 10^{-9}$ N)
6	→ ← ⊕ 0.1 ⊖	23
1	→ ← ⊕ 0.2 ⊖	5.75
7	→ ← ⊕ 0.3 ⊖	2.6
8	→ ← ⊕ 0.4 ⊖	1.43

Particles are not drawn to scale.
One nanometer is one billionth of a meter. Its abbreviation is nm.
One Newton is abbreviated as N.

KEY
⊕ = Proton (charge of +1) ⊖ = Electron (charge of −1)
→ ← = Attractive force between oppositely-charged particles

Use the information in Model 2 to answer questions 11 – 21.
Reach agreement with your team before writing down your consensus answers.

11. Compare the titles of Model 1 and Model 2. Write **two** differences between them.

12. Look closely at the headings of each column in the data table in Model 2. What is the symbol for the term **Electrostatic Force**?

13. **Highlight** the row in Model 2 that shows one proton and one electron located 0.2 nanometers apart.

    a. Do the data in this row match the **highlighted** row in Model 1?

    b. Explain why your answer makes sense.

14. Focus on the column labeled **Distance between particles** in Model 2.
Do the numbers decrease, stay the same, or increase?

    *As you look from top to bottom of the column, the **distance** values…*

15. Focus on the column labeled **Electrostatic Force** in Model 2.
Do the numbers decrease, stay the same, or increase?

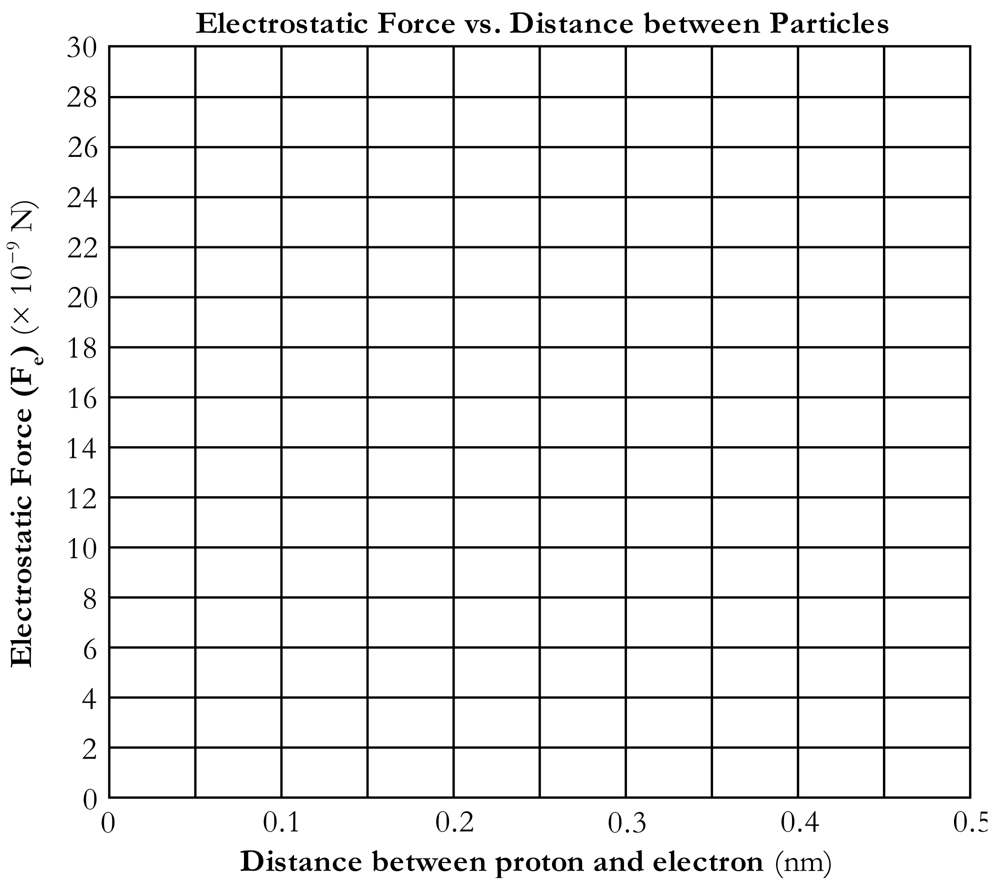
    As you look from top to bottom of the column, the F_e values…

16. Write one sentence that describes the relationship between **d** and $\mathbf{F_e}$.
Include one or more of these terms or phrases in your sentence: decreases, stays the same, increases. You may use symbols in your sentence.

17. Use the data from Model 2 to create a graph.

a. **Plot** the data from all four situations in Model 2.

b. **Draw** a line of best fit (straight line or smooth curve) to connect the points you plot.



Send a spy to check your graph with two other teams before you continue.

18. Circle the one statement below that best summarizes the meaning of your graph.

a. As the **distance between oppositely-charged particles (d)** increases, the $\mathbf{F_e}$ increases at a steady rate (linearly).

b. As **d** increases, the $\mathbf{F_e}$ decreases at a steady rate (linearly).

c. As **d** increases, the $\mathbf{F_e}$ increases more and more quickly.

d. As **d** increases, the $\mathbf{F_e}$ decreases more and more slowly.

19. Use your graph in question 17 to answer the following questions.

a. An electron is located 0.15 nm away from a proton. Estimate the $\mathbf{F_e}$ between the two charged particles. Show your work by drawing on the graph.

$\mathbf{F_e}$ = ___________ x 10^{-9} N

b. A proton and an electron are located 0.35 nm apart. Estimate the $\mathbf{F_e}$ between the two charged particles. Show your work by drawing on the graph.

$\mathbf{F_e}$ = ___________ x 10^{-9} N

Read This!

We have investigated how the amount of charge (numbers of particles) and the distance between particles affect the electrostatic force between oppositely-charged particles. Let's explore the mathematical relationships among these variables so we can predict how electrostatic force reacts to changes in the amount of charge or the distance between particles.

From math class we recall these terms to describe relationships between two variables.
In a **direct relationship**, as one variable ↑, the other variable also ↑.
In an **inverse relationship** (indirect relationship), as one variable ↑, the other variable ↓.

20. Look back at Model 1. Is the relationship between **amount of charge** and $\mathbf{F_e}$ direct or inverse?

21. Look back at Model 2. Is the relationship between **d** and $\mathbf{F_e}$ direct or inverse?

Check your answers to questions 20 and 21 with your teacher before you continue.