Gizmos

Name: ______________________________________ Date: ________________________

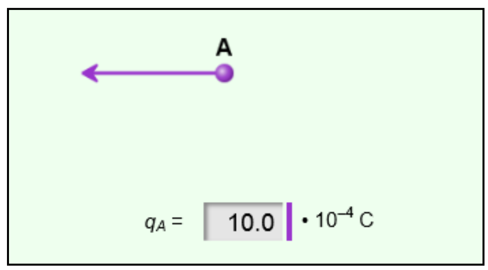
# Student Exploration: Coulomb Force (Static)

**Vocabulary:** Coulomb's law, electrostatic force, vector

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)
Have you ever taken clothes out of the dryer and found a sock stuck to your underwear? Static cling is an example of **electrostatic forces**, or the forces that exist between charged objects.

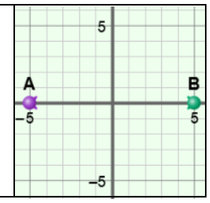
1. How do you think the sock and underwear became charged? ________________________
   ___________________________________________________________________________
2. Suppose two socks acquire the same charge. Do you think they would stick together? ____
   Explain: ___________________________________________________________________
   ___________________________________________________________________________

**Gizmo Warm-up**
As clothes are tumbled in a dryer, electrons are rubbed off some items, giving them a positive charge, and deposited on other items, giving them a negative charge. These charged items exert electrostatic forces on one another. You can explore these forces with the *Coulomb Force (Static)* Gizmo.




In its initial settings, the Gizmo shows two objects that each have a charge ($q$) of $10.0 \times 10^{-4}$ C (coulombs). Turn on the **Show force vector** checkboxes for objects **A** and **B**. The arrows coming from each object are **vectors** that represent the electrostatic force. The direction and length of each vector show the direction and magnitude (strength) of each force.

1. Are the vectors for objects **A** and **B** pointing together or away from each other? __________
2. Are objects **A** and **B** attracted together or repelled apart? ___________________________
3. Compare the lengths of the vectors. What do you notice? ___________________________
   ___________________________________________________________________________

| | | |
|---|---|---|
| **Activity A:**<br><br>**The effect of charge** | Get the Gizmo ready:<br>• Turn on **Show grid**. Place object **A** on the *x*-axis at -5 and object **B** on the *x*-axis at +5.<br>• Check that **Show force vector** is turned on for each object. |  |

**Question: How does charge affect the strength of the electrostatic force?**

1. Observe: You can change the charge of each object by entering the desired value in the $q_A$ and $q_B$ boxes. Observe the force vectors for each of the situations listed in the table below. Based on the force vectors, state whether the objects are repelled from one another, attracted to one another, or if there is no force at all.

| $q_A$ | $q_B$ | Attraction, repulsion, or no force? |
|---|---|---|
| $1.0 \times 10^{-4}$ C | $1.0 \times 10^{-4}$ C | |
| $-1.0 \times 10^{-4}$ C | $1.0 \times 10^{-4}$ C | |
| $-1.0 \times 10^{-4}$ C | $-1.0 \times 10^{-4}$ C | |
| $1.0 \times 10^{-4}$ C | $0.0 \times 10^{-4}$ C | |

2. Make a rule: Complete the following sentences with the words “attract,” “repel,” or “zero.”

   *When the charges are the same, the two objects ____________ one another.*

   *When the charges are opposite, the two objects ____________ one another.*

   *When one of the objects has no charge, the resulting force is ____________.*

3. Predict: How do you think the magnitude of the electrostatic force between two objects will change if the charge of each object was doubled? ________________________________

4. Measure: Turn on **Show vector notation** for both objects. Set the charge of objects **A** and **B** to $1.0 \times 10^{-4}$ C. The force on object **A** is now -0.90**i** + 0**j** N. That means that the force is -0.90 N in the *x* direction and 0 N in the *y* direction.

   A. What is the magnitude of the force on object **A**? $|\mathbf{F}_A|$ = ____________

   B. What is the magnitude of the force on object **B**? $|\mathbf{F}_B|$ = ____________

   C. The force on object **A** is negative. What does this indicate about the direction of the force? ____________________________________________________________

**(Activity A continued on next page)**

**Activity A (continued from previous page)**

5. Gather data: For each charge combination listed in the table below, write magnitude of the force on object **A**. (Note: The magnitude of the force, or its strength, is always positive.)

| $q_A$ | $q_B$ | $\|F_A\|$ | **Factor** | $q_A \times q_B$ |
|---|---|---|---|---|
| $1.0 \times 10^{-4}$ C | $1.0 \times 10^{-4}$ C | | | |
| $1.0 \times 10^{-4}$ C | $2.0 \times 10^{-4}$ C | | | |
| $2.0 \times 10^{-4}$ C | $2.0 \times 10^{-4}$ C | | | |
| $2.0 \times 10^{-4}$ C | $3.0 \times 10^{-4}$ C | | | |

6. Analyze: What patterns do you notice in the data? ___________________________________

_____________________________________________________________________________

7. Calculate: To calculate how much the force is multiplied, divide each force by the first value, 0.90 N. Fill in these values under **Factor** in the table.

   What do you notice? ___________________________________________________________

8. Calculate: Calculate the product of the two charges, and fill in these values in the last column. Compare these numbers to the **Factor** numbers.

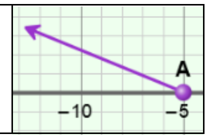
   What do you notice? ___________________________________________________________

9. Apply: What would you expect the force to be if the charge of object **A** was $5.0 \times 10^{-4}$ C and the charge of object **B** was $4.0 \times 10^{-4}$ C? __________________________________________

   Check your answer with the Gizmo.

10. Challenge: Based on what you have learned, write an equation for the strength of the electrostatic force for two charges that are separated by 10 meters. Use the Gizmo to check your equation.

$$F =$$

| | | |
|---|---|---|
| **Activity B:**<br><br>**The effect of distance** | Get the Gizmo ready:<br>• Turn on **Show distance**.<br>• Set $q_A$ to 10.0 × $10^{-4}$ C and $q_B$ to 1.0 × $10^{-4}$ C. |  |

**Question: How does distance affect the strength of the electrostatic force?**

1. Observe: Move object **A** back and forth. How does the distance between the objects affect the strength of the electrostatic force between them?

   ________________________________________________________________________

2. Predict: How do you think the electrostatic force between two objects would change if the distance between the two objects was doubled? ___________________________________

3. Measure: Place object **A** on the *x*-axis at -2, and object **B** on the *x*-axis at +1.

   A. What is the magnitude of the force on object **A**? $|F_A|$ = ____________

   B. What is the magnitude of the force on object **B**? $|F_B|$ = ____________

4. Gather data: Check that $q_A$ is 10.0 × $10^{-4}$ C and $q_B$ is 1.0 × $10^{-4}$ C. For each position of object **A**, record the distance between the objects and the force on object **A**.

| **Object A** | **Object B** | **Distance (m)** | $|F_A|$ **(N)** | **Distance factor** | **Force factor** | $\frac{1}{\text{Dist. factor}^2}$ |
|---|---|---|---|---|---|---|
| (-2, 0) | (1, 0) | | | | | |
| (-5, 0) | (1, 0) | | | | | |
| (-11, 0) | (1, 0) | | | | | |
| (-14, 0) | (1, 0) | | | | | |

5. Calculate: To calculate the distance factor, divide each distance by the original distance (3 m). To calculate the force factor, divide each force by the original force (100 N).

   A. How does the force change as the distance increases? ________________________

   __________________________________________________________________

   B. Now find the reciprocal of each distance factor squared. What do you notice?

   __________________________________________________________________

**(Activity B continued on next page)**

**Activity B (continued from previous page)**

6. Apply: What would you expect the force to be if the distance was 30 meters? ____________

   How did you come up with your answer? ________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

   Use the Gizmo to check your answer.

7. Make a rule: Based on what you have learned, write an equation to calculate the force between two objects if the product of their charges is $1.0 \times 10^{-7}$ C. Use the Gizmo to test your formula. (Note: Use the variable *R* for the distance between the charges.)

   *F* =

8. Summarize: Fill in the blanks. *The electrostatic force between two objects is proportional to the ____________________ of the distance ____________________.*

9. Challenge: **Coulomb's law** is an equation that relates the electrostatic force between two objects to their distance and charge. In activity A, you found that the electrostatic force between two objects is proportional to the product of their charges. Combine that with what you have learned in this activity to complete Coulomb's law below. (Hint: In the equation, *k* is a constant.) Check your answer with your teacher.

   $$F = k\,\frac{\square \times \square}{\square}$$

10. On your own: Use the Gizmo to find the value of *k* in the formula above. List the value and describe how you found it below. The units of *k* are newton · meter$^2$ ÷ coulombs$^2$, or N·m$^2$/C$^2$. Check your answer with your teacher.

    *k* = _____________________

    Show your work: