Online Lab: Coulomb's Law

Name: Date:

Instructor: Section:

Objective:

This lab you will determine the factors which affect the electrostatic force, F_E, between two charges, q_1 and q_2 as well as determine the relationship between F_E, q_1, q_2, and r. Then graphically determine the value of Coulomb's Constant, k.

Theory:

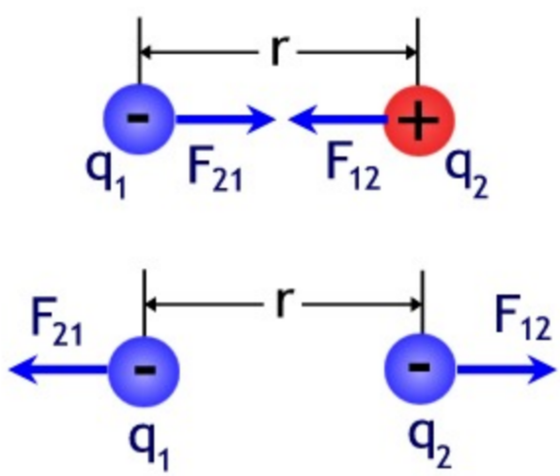
Electrostatic force between two charges is (a) directly proportional to the magnitude of the product the two charges and (b) inversely proportional to the square of the distance between their centers.

If q_1 and q_2 are the magnitude of the two point charges, and r is the distance between their centers, electrostatic force between them is expressed by the equation below.

$$F_E = k\frac{|q_1||q_2|}{r^2} \tag{1}$$

where k is a constant of proportionality, called Coulomb's constant, k= 8.99 x 10^9 N $\cdot$ m^2/C^2.

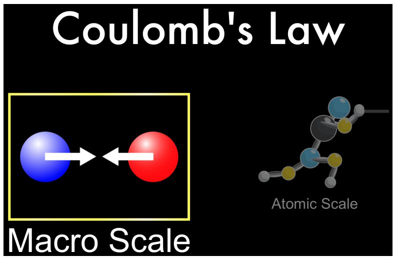
Coulomb's law of Electrostatic Force states that a charged particle attracts or repels other charged particles with a force which is directly proportional to the product of their charges and inversely proportional to the square of the distance between their centers.



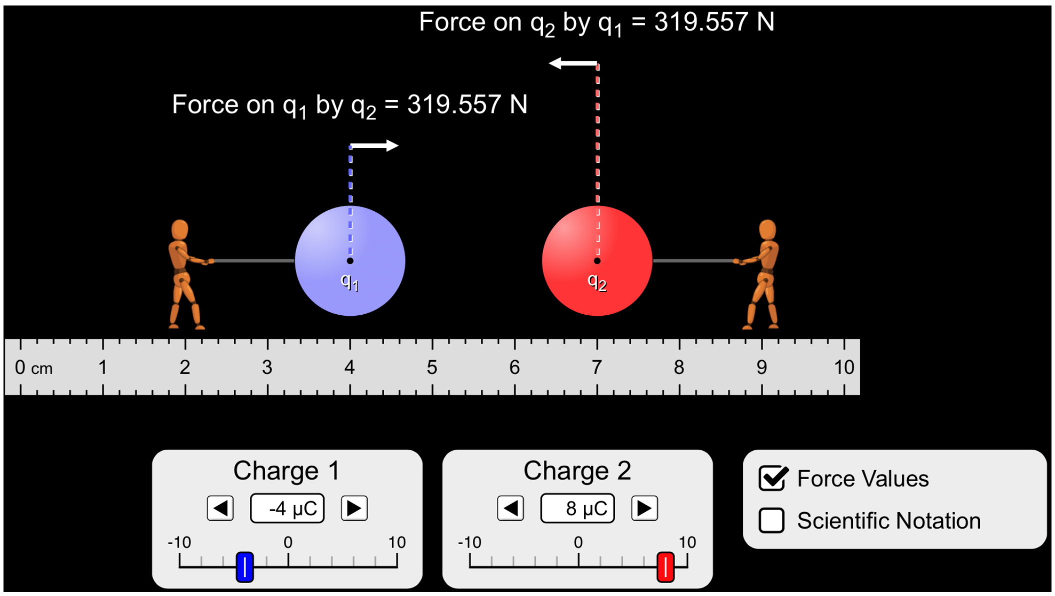
Online Experiment Setup Instructions:

1. Go to the following website:
   https://phet.colorado.edu/sims/html/coulombs-law/latest/coulombs-law_en.html

2. Click Macro Scale on the PHeT simulation.



3. The simulation should look like the image below.



4. You can control the value of the charges, q_1 and q_2 with the sliders on the bottom.

5. The distance between the charges, r, can be changed by dragging either charge left or right. Always measure from the CENTER of the left charge, q_1, to the CENTER of the right charge, q_2.

6. The force value is represented by white vectors as well as a magnitude in Newtons, N.

Fixed Distance, Changing Charge

1. Place q_1 and q_2 4 cm apart.
2. **SET** the values of q_1 to -7 μC and q_2 to 10 μC.
3. Record the force on q_1 by q_2, F_{21} and the force on q_2 by q_1, F_{12} in Table 2.
4. Record if the force arrows are pointing (**Toward** or **Away**) from each other in Table 3.
5. Repeat Steps 2 - 4 for each q_2 value in Column 2.

Table 1: Data Results: Fixed Distance, Changing Charge

q_1 (μC)	q_2 (μC)	r **(cm)**	F_{21} **(N)**	F_{12} **(N)**	**Away - A** **Toward - T**
-7 μC	10 μC	4 cm			
-7 μC	8 μC	4 cm			
-7 μC	6 μC	4 cm			
-7 μC	4 μC	4 cm			
-7 μC	2 μC	4 cm			
-7 μC	0 μC	4 cm			
-7 μC	-2 μC	4 cm			
-7 μC	-4 μC	4 cm			
-7 μC	-6 μC	4 cm			
-7 μC	-8 μC	4 cm			
-7 μC	-10 μC	4 cm			

Observation and Analysis:

1. What happens to F_{21} when you doubled q_2 while leaving the q_1 constant?
   Select from: Stays the same, Doubles, Halves, Quadruples

2. If q_2 is held constant and q_1 is reduced by a factor of 3, what happens to F_{21}?
   Select from: Stays the same, Triples, Reduced to 1/3 of original value, or Reduced to 1/9 of original value

Fixed Charge, Changing Distance

1. **SET** the values of q_1 and q_2 to 10 μC.
2. DRAG q_1 all the way to the left at the 0 cm mark.
3. DRAG q_2 all the way to the right at the 10 cm mark.
4. Record the force on q_1 due to q_2, F_{12} in Table 2, Column 6.
5. Repeat Steps 3 - 4 for distance of 9, 8, 7, 6, 5, 4, 3, and 2 cm.
6. Convert the distance (r) from **cm** to **m**. Record these values in Table 2, Column 4.
7. Calculate $1/r^2$ in meters (m) for each distance. Record these values in Table 2, Column 5.

Table 2: Data Results: Fixed Charge, Changing Distance

q_1 (μC)	q_1 (μC)	r **(cm)**	r **(m)**	$1/r^2$ **(m)**	F_{12} **(N)**
10 μC	10 μC	10 cm			
10 μC	10 μC	9 cm			
10 μC	10 μC	8 cm			
10 μC	10 μC	7 cm			
10 μC	10 μC	6 cm			
10 μC	10 μC	5 cm			
10 μC	10 μC	4 cm			
10 μC	10 μC	3 cm			
10 μC	10 μC	2 cm			

Observation and Analysis:

1. Based on your data above, describe the relationship between Electrostatic Force, F_E, and distance between the charges, r. Check the box next to your choice below.

   A. **Inverse**, $F_E \propto 1/\mathbf{r}$ (e.g. If r triples, F_E is reduced by a factor of $1/3$)

   B. **Inverse Square**, $F_E \propto 1/r^2$ (e.g. If r triples, F_E is reduced by a factor of $1/3^2$)

   C. **Direct**, $F_E \propto \mathbf{r}$ (e.g. If r triples, F_E increases by 3)

   D. **Quadratic or Square**, $F_E \propto r^2$ (e.g. If **r** triples, F_E increases by 3^2)

Conclusions

1. Using your data in Table 2, Columns 4 and 6, create a graph of F_{12} on the Y-axis versus r on the X-axis. Label the x-y axes including units and Title your graph "**Coulomb Force vs Charge Separation**". Upload it with this Lab Report in D2L. Comment on the graph.

2. Using your data in Table 2, Columns 5 and 6, create a graph of F_{12} on the Y-axis versus $\frac{1}{r^2}$ on the X-axis. Label the x-y axes including units and Title your graph "**Coulombs Law**". Upload it with this Lab Report in D2L. Measure and record the slope of the line using any method you are comfortable with. What is the physical meaning of the slope?
NOTE: When you get the slope you should get something like 0.8987 which is in (N * m^2). Then you divide that by q^2 or (10 $\times$ 10^{-6})^2 with units of C^2.

3. Discuss how well does your measured k value compare to ($k_{known} = 8.9 \times 10^9$ N $\cdot$ m^2/C^2). Compare the experimental value of Coulomb's constant, $k_{measured}$ with the accepted value k_{known} using the equation below.

$$\%_{Error} \;=\; \left(\frac{k_{measured} - k_{known}}{k_{known}}\right) \times\ 100 \qquad (2)$$

4. Electric force is a force of attraction or repulsion between objects based on their charges and their distance apart. When is the electric force attractive?

5. When is the electric force repulsive?

6. Does the electric force increase or decrease as objects move closer together?

7. What evidence do you see that Newton's third law applies to electrostatic forces?