Coulomb's Law
Lesson Notes

Focus Questions:
- What is the equation that describes the electrical force between two charged objects?
- How can this equation be used in the solving of Physics word problems?

Action-at-a-Distance
Identify the three types of charge interactions experienced by a charged object:
- Like-charged objects _____.
- Oppositely-charged objects _____.
- A charged and neutral object _____.

These interactions result in **non-contact forces**. They occur even when objects are **not** touching. They are examples of an action-at-a-distance.

Coulomb's Law
The force of attraction or repulsion between two charged objects is …
- directly proportional to the product of their charges
- inversely proportional to the square of their separation distance

$$F_{elect} \propto \frac{Q_A \cdot Q_B}{d^2}$$

Q stands for the quantity of charge on Object A and B

d stands for the distance between the centers of A and B

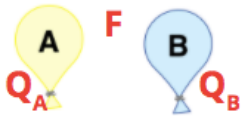
As an equation, Coulomb's Law is stated using the above symbols and a proportionality constant (**k**). This proportionality constant is referred to as the **Coulomb's Law constant**. Its units determine the units that must be used when substituting values into the equation for F, Q, and d.

$$F_{elect} = k \cdot \frac{Q_A \cdot Q_B}{d^2}$$

$$k = 9.0 \times 10^9\ N \cdot m^2/C^2$$

The Coulomb's Law equation is typically used in one of two ways: as a **guide to thinking** about how a change in one of the variables affects the other variables (proportional reasoning) and as an algebraic recipe for predicting the numerical value of the one of the quantities if given the value of the other quantities.

Proportional Reasoning
The electric force (F_{elect}) is directly proportional to the product of the charges ($Q_A \cdot Q_B$).



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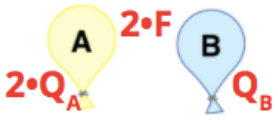
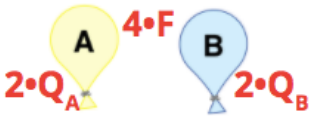
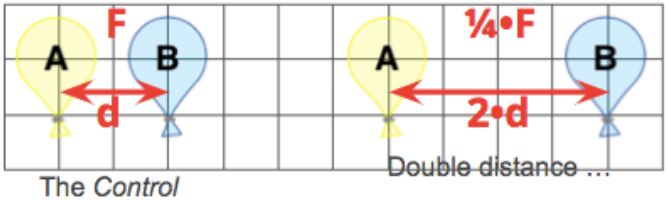


Double a charge … double the force



Double both charges … quadruple the force

The force (F_{elect}) is inversely proportional to the square of the separation distance (d^2).



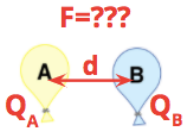
The *Control*

Double distance … 1/4th the force

Algebraic Problem-Solving

1. Read problem/diagram.
2. Identify known values.
3. Identify unknown variable.
4. Select formula for use.
5. Substitute and solve.

Example 1: Two balloons are charged with an identical quantity and type of charge: -6.25 μC. They are held apart at a separation distance of 61.7 cm. Determine the magnitude of the electrical force of repulsion between them.



Known: $Q_A = Q_B = 6.25\ \mu C = 6.25 \times 10^{-6}\ C$ $d = 61.7\ cm = 0.617\ m$

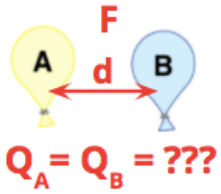
Unknown: $F_{elect} = ???$

$F_{elect} = (9.0 \times 10^9\ N \cdot m^2/C^2) \cdot Q_A \cdot Q_B / d^2$

$F_{elect} = (9.0 \times 10^9\ N \cdot m^2/C^2) \cdot (6.25 \times 10^{-6}\ C)^2 / (0.617\ m)^2$

$F_{elect} = 0.923\ N$

Example 2: Two balloons with the same amount of charge repel with 0.0648 N of force when held at a separation distance of 28.2 cm. Determine the quantity of charge on the balloons.



Known: $F_{elect} = 0.0648\ N$ $d = 28.2\ cm = 0.282\ m$

Unknown: $Q_A = Q_B = ???$

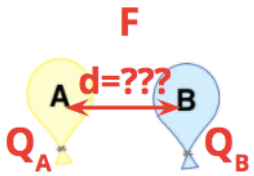
$F_{elect} = k \cdot Q_A \cdot Q_B / d^2$ ➡ $Q_A \cdot Q_B = F_{elect} \cdot d^2 / k$

$Q_A \cdot Q_B = F_{elect} \cdot d^2 / k$

$Q^2 = (0.0648\ N) \cdot (0.282\ m)^2 / (9.0 \times 10^9\ N \cdot m^2/C^2) = 5.725...x10^{-13}\ C^2$

$Q = \sqrt{(5.725...x10^{-13}\ C^2)} =$ **$7.57x10^{-7}\ C$** (0.757 μC)

Example 3: Two different objects are given charges of +3.27 μC and -4.91 μC. What separation distance will cause the force of attraction between the two objects to be 0.358 N?



Known: $Q_A = +3.27\ \mu C = +3.27x10^{-6}\ C$ $Q_B = -4.91x10^{-6}\ C$
$F_{elect} = 0.358\ N$

Unknown: $d = ???$

$F_{elect} = k \cdot Q_A \cdot Q_B / d^2$ ➡ $d^2 = k \cdot Q_A \cdot Q_B / F_{elect}$

$d^2 = k \cdot Q_A \cdot Q_B / F_{elect} \Rightarrow d = \sqrt{(k \cdot Q_A \cdot Q_B / F_{elect})}$

$d = \sqrt{(9.0 \times 10^9\ N \cdot m^2/C^2) \cdot (3.27x10^{-6}\ C) \cdot (4.91x10^{-6}\ C) / (0.358\ N)}$

$d = \sqrt{(0.4036 \ldots\ m^2)} =$ **$0.635\ m$** (63.5 cm)