

Part A: Patterns and Direction

No calculator needed. Use the patterns in Coulomb's law.

1. Two small charged spheres push on each other with a force of 12 N. Find the new force for each change. Treat each change separately, starting from the original 12 N.

Change	New force
Double one of the charges	24 N
Triple the distance	1.3 N
Cut the distance in half	48 N
Double both charges and double the distance	12 N

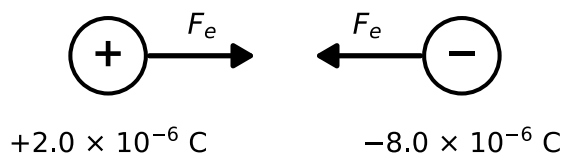
Double one charge: force is proportional to each charge, so $2 \times 12 \text{ N} = \mathbf{24 \text{ N}}$.

Triple the distance: $1/d^2$ gives $1/9$, so $12 \text{ N} \div 9 = \mathbf{1.3 \text{ N}}$.

Halve the distance: $(1/2)^2$ in the bottom means 4 times the force, so **48 N**.

Double both, double distance: $2 \times 2 = 4$ times bigger from charge, $2^2 = 4$ times smaller from distance, so the force stays **12 N**.

2. The two charges below are a fixed distance apart.



- Draw an arrow on each charge to show the direction of the electric force on it.
- The $-8.0 \times 10^{-6} \text{ C}$ charge is 4 times larger. Which charge feels the bigger force? Explain.
 - Opposite charges **attract**, so the arrow on the + charge points right (toward the – charge) and the arrow on the – charge points left (toward the + charge).
 - Neither. The forces are equal in size.** Both charges appear in the same equation, $F_e = kq_1q_2/d^2$, and the forces are a Newton's third law pair: each charge pulls on the other just as hard.

Part B: Using Coulomb's Law

Use $F_e = kq_1q_2/d^2$ with $k = 9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$. Plug in sizes of charges, then state the direction in words. Show knowns, equation, substitution, and answer.

3. Two charged beads, $+5.0 \times 10^{-6} \text{ C}$ and $+2.0 \times 10^{-6} \text{ C}$, sit 0.30 m apart on a table. What is the electric force between them? Is it attractive or repulsive?

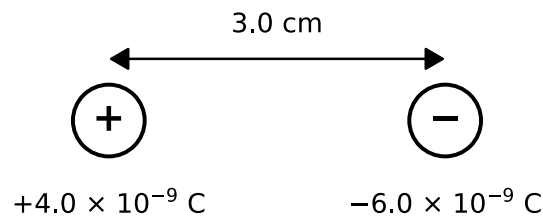
Knowns: $q_1 = 5.0 \times 10^{-6} \text{ C}$, $q_2 = 2.0 \times 10^{-6} \text{ C}$, $d = 0.30 \text{ m}$, $k = 9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$

Equation: $F_e = kq_1q_2/d^2$

Substitute: $F_e = (9.0 \times 10^9)(5.0 \times 10^{-6} \text{ C})(2.0 \times 10^{-6} \text{ C}) / (0.30 \text{ m})^2 = 0.090 / 0.090$

Answer: $F_e = 1.0 \text{ N}$, **repulsive** (like charges push apart)

4. Two specks of dust in a dryer have the charges shown and are 3.0 cm apart. What is the electric force between them? (Convert the distance to meters first.)



Knowns: $q_1 = 4.0 \times 10^{-9} \text{ C}$, $q_2 = 6.0 \times 10^{-9} \text{ C}$ (sizes), $d = 3.0 \text{ cm} = 0.030 \text{ m}$, $k = 9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$

Equation: $F_e = kq_1q_2/d^2$

Top: $(9.0 \times 10^9)(4.0 \times 10^{-9})(6.0 \times 10^{-9}) = 2.16 \times 10^{-7} \text{ N}\cdot\text{m}^2$. **Bottom:** $(0.030 \text{ m})^2 = 9.0 \times 10^{-4} \text{ m}^2$

Answer: $F_e = 2.16 \times 10^{-7} \div 9.0 \times 10^{-4} = 2.4 \times 10^{-4} \text{ N}$, **attractive** (opposite charges)

5. A $+3.0 \times 10^{-6} \text{ C}$ charge and a $+6.0 \times 10^{-6} \text{ C}$ charge repel each other with a force of 0.45 N. How far apart are they?

Knowns: $q_1 = 3.0 \times 10^{-6} \text{ C}$, $q_2 = 6.0 \times 10^{-6} \text{ C}$, $F_e = 0.45 \text{ N}$, $k = 9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$

Rearrange: $d^2 = kq_1q_2/F_e$

Substitute: $d^2 = (9.0 \times 10^9)(3.0 \times 10^{-6})(6.0 \times 10^{-6}) / 0.45 = 0.162 / 0.45 = 0.36 \text{ m}^2$

Answer: $d = \sqrt{0.36 \text{ m}^2} = 0.60 \text{ m}$

6. Two identical charged balloons hang 0.50 m apart (center to center) and repel each other with a force of 0.90 N. What is the size of the charge on each balloon? Can you tell whether the balloons are positive or negative? Explain.

Knowns: $q_1 = q_2 = q$, $d = 0.50 \text{ m}$, $F_e = 0.90 \text{ N}$, $k = 9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$

Rearrange: $F_e = kq^2/d^2$, so $q^2 = F_e d^2 / k$

Substitute: $q^2 = (0.90 \text{ N})(0.50 \text{ m})^2 / (9.0 \times 10^9) = 0.225 / (9.0 \times 10^9) = 2.5 \times 10^{-11} \text{ C}^2$

Answer: $q = \sqrt{2.5 \times 10^{-11} \text{ C}^2} = 5.0 \times 10^{-6} \text{ C}$ on each balloon

They repel, so they have the **same sign**, but the force alone cannot tell us whether both are positive or both are negative.