B2 · Coulomb’s law

Student notes - follow the slides, fill the blanks, work the questions

Calculate a pair force, predict changes, and interpret an inverse-square graph.

Name: _____ Date: _____

Slide 1 of 7 · How the force changes

In B1, like charges repelled and unlike charges attracted. This lesson finds how strong that force is.

Symbols: q_1 and q_2 are the two charges in _____; r is the distance between them in _____; F is the size of the force in _____.

Each charge is its own factor. Double one charge: force × _____. Double both charges: force × 2 × 2 = × _____.

Distance: F ∝ _____. The symbol ∝ means _____. Double r: force × _____. Triple r: force × _____.

Rule: write each change as a _____, then _____. For distance, _____ the change, then _____ it. A graph of F against $1/r^2$ is a _____.

Example. Two charges exert a force of 0.800 N on each other. Both charges are doubled in size and the distance between them is tripled. What is the new force?

Work:

Answer: _____

Try it. Two charges exert a force of 0.150 N on each other. One charge becomes three times larger and the distance is cut in half. What is the new force?

Work:

Answer: _____

Slide 2 of 7 · Coulomb’s law

Slide 1 showed how the force changes. One equation holds all of those rules.

Coulomb’s law gives the size of the force between two _____. A point charge is a _____. Formula: F = _____, with k = _____. F is in _____.

Bars | | mean _____: drop any minus sign. Convert µC to C by multiplying by _____. The distance r is in _____, measured from _____.

The signs give the direction: like charges _____, unlike charges _____. Choose each arrow from the _____, not from a minus sign in the answer.

Newton’s third law: each charge feels the _____ of force. To find r, rearrange first: multiply both sides by r^2, divide by F, then take the _____: r = _____.

Example. A +3.0 µC sphere and a −5.0 µC sphere are 0.30 m apart. Use k = 8.99 × 10^9 N·m^2/C^2. What is the size of the force on each sphere, and does the force attract or repel?

Work:

Answer: _____

Try it. A +2.0 µC sphere and a +4.0 µC sphere repel each other with a force of 0.500 N. What is the distance between them?

Work:

Answer: _____

Slide 3 of 7 · Method: what happens to the force

These are the steps you used on slide 1.

Step 1: write the formula _____. The constant k never changes, so it _____.

Step 2: list the _____ in words, such as “q_1 doubles” or “r triples”.

Step 3: make one _____ for each change. A charge that changes by n gives a factor of _____. A distance that changes by n gives _____: flip it, then square it.

Step 4: _____ the factors. Keep the total as a _____, such as 2 × 2 × 1/9 = 4/9.
Step 5: new force = old force × the _____. Check: a bigger charge or a smaller distance must make the force _____.

Example. Two charges exert a force of 0.800 N on each other. Both charges are doubled in size and the distance between them is tripled. What is the new force?

Work:

Answer: _____

Try it. Two charges exert a force of 0.500 N on each other. The distance is doubled and one charge is tripled. What is the new force? Write each step number beside your work.

Work:

Answer: _____

Slide 4 of 7 · Method: force between two charges

These are the steps you used on slide 2.

Step 1: list the givens in _____ (μC × 10^{-6}) and _____.

Step 2: use the _____ of the charges. Drop any minus sign, because the size of a force is never _____.

Step 3: put the numbers into F = _____, with k = _____. Square the _____.

Step 4: use the signs for the direction. Like charges _____; unlike charges _____. Each charge feels the _____ of force. Check: the unit is _____ and the power of ten fits the picture.

Example. A +3.0 μC sphere and a −5.0 μC sphere are 0.30 m apart. Use k = 8.99 × 10^9 N·m²/C². What is the size of the force on each sphere, and does the force attract or repel?

Work:

Answer: _____

Try it. Two +4.0 μC spheres are 0.20 m apart. Use k = 8.99 × 10^9 N·m²/C². What is the size of the force on each sphere, and does the force attract or repel? Write each step number beside your work.

Work:

Answer: _____

Slide 5 of 7 · How was Coulomb’s law found?

Slide 2 gave Coulomb’s law. How did Coulomb find it, long before modern meters?

In _____ Coulomb measured the force between two small charged balls with a _____. A thin _____ holds a light rod. A force on the rod _____ the fibre.

The twist angle is _____ to the force. A scale around the rod shows the _____. A thin fibre twists even for a very _____ force.

Coulomb could not measure charge directly. He touched a charged sphere to an _____ uncharged sphere. The charge is shared _____, so each has _____.

Cavendish used the same kind of twisting balance to measure the _____ force between heavy _____ masses. Both balances turn a tiny force into a twist _____.

Example. A metal sphere carries +8.0 µC. It touches an identical metal sphere that is uncharged. They are then separated. What is the charge on each sphere?

Work:

Answer: _____

Try it. NEW, for teacher review. Say what the scale reading of a torsion balance tells you, and why Coulomb used a very thin fibre.

Work:

Answer: _____

Slide 6 of 7 · Electric force and gravity

In Physics 20, gravity also had a law with $1/r^2$. Compare it with Coulomb's law from slide 2.

Newton's law of gravitation: F_g = _____, where G = _____ and m is mass in _____. Coulomb's law: F_e = _____. The two laws have the _____.

Both forces depend on a _____ and fall as _____. Both come in _____ pairs.

Gravity only _____: there is one kind of mass. The electric force can _____: there are two kinds of charge. For an electron and a proton the electric force is about _____ times bigger.

Most large objects are _____: their electric forces cancel, so _____ wins. A ratio is one force _____ the other. When both use the same r, the _____ cancels.

Example. An electron and a proton are the same distance r apart. Find the ratio $F_e \div F_g$. Use $k = 8.99 \times 10^{9}$, $G = 6.67 \times 10^{-11}$, $e = 1.60 \times 10^{-19}$ C, m(proton) = 1.67×10^{-27} kg and m(electron) = 9.11×10^{-31} kg.

Work:

Answer: _____

Try it. Check the exponent: in the ratio above, which constants are in the top and which in the bottom? Write the ratio as a formula, then say why the answer is so large.

Work:

Answer: _____

Slide 7 of 7 · Two-step problems

B1 shared charge between spheres that touch. Slide 2 found the force. This slide joins the two.

Two events, two steps. The force uses the charges _____, not the ones the spheres started with. So the _____ comes first and the _____ second.

Step one: share the charge. Identical spheres share the total _____. _____ the signed charges, then divide by _____. A negative value takes away from a positive one.

Step two: use the new charges in F = _____. Convert μC to _____ and use _____. Both charges the same sign give _____; one of each sign gives _____.

Factor questions: decide which way each change pushes the force. Half the distance: factor _____. Half one charge: factor _____. Write both factors, _____ them, then multiply by the old force.

Example. Two identical metal spheres carry +6.0 μC and −2.0 μC. They touch and are separated, and then they are placed 0.10 m apart. What is the size of the force on each sphere, and does it attract or repel?

Work:

Answer: _____

Try it. Two small charged spheres 0.40 m apart exert a force of 2.4 N on each other. They are moved to 0.20 m apart, and the charge on one of them is replaced by half its original size. What is the new force? A. 1.2 N. B. 2.4 N. C. 4.8 N. D. 9.6 N.

Work:

Answer: _____

Sketch (draw and label the diagram):

B2 · Practice

Coulomb’s law | Questions 1-2 of 12

Use $k = 8.99 \times 10^9\ N \cdot m^2/C^2$ and $g = 9.81\ m/s^2$ where needed. These values are from the Alberta Physics 30 data sheets, Constants section. All point-charge calculations approximate air as vacuum.

Easy · B2-P01. Convert each value to SI units: (a) +4.50 µC, (b) −8.00 nC, (c) 25.0 cm. Keep the charge signs.

Work:

Final answer (with unit and sign): _____

Easy · B2-P02. A positive charge A is left of a negative charge B. Draw the electric-force arrow on each. If the force magnitude on B is 0.240 N, what is the force on A?

Work:

Final answer (with unit and sign): _____

B2 · Practice

Coulomb’s law | Questions 3-4 of 12

Easy · B2-P03. Two charges exert 0.720 N. Keep both charges fixed and triple their distance. What is the new force magnitude? Explain the factor.

Work:

Final answer (with unit and sign): _____

Easy · B2-P04. Keep the distance and q_2 fixed, but double $|q_1|$. What happens to the electric-force magnitude? Would doubling the distance instead give the same change? Explain.

Work:

Final answer (with unit and sign): _____

B2 · Practice

Coulomb’s law | Questions 5-6 of 12

Medium · B2-P05. Two point charges in air are A = +3.00 μC on the left and B = +2.00 μC on the right, separated by 0.200 m. What is the force on B, including direction? Use $k = 8.99 \times 10^9$ N·m²/C².

Optional start: Draw the force on B before substituting.

Work:

Final answer (with unit and sign): _____

Medium · B2-P06. Two point charges in air are A = −5.00 nC on the left and B = +8.00 nC on the right, 4.00 cm apart. What is the force on B? Use $k = 8.99 \times 10^9$ N·m²/C².

Work:

Final answer (with unit and sign): _____

B2 · Practice

Coulomb’s law | Questions 7-8 of 12

Medium · B2-P07. Two point charges have magnitudes 2.00 μC and 5.00 μC. Their force magnitude in air is 0.500 N. How far apart are they? Use $k = 8.99 \times 10^9$ N·m²/C². Can the force direction be determined from these data?

Optional start: Isolate r^2, then take a square root.

Work:

Final answer (with unit and sign): _____

Medium · B2-P08. With the charges fixed, doubling the distance changes an electric-force magnitude from 0.800 N to what value? Apply the same change to a gravitational force initially 0.120 N. Explain one similarity and one difference between the two forces.

Work:

Final answer (with unit and sign): _____

B2 · Practice

Coulomb’s law | Questions 9-10 of 12

Challenging · B2-P09. The initial force magnitude is 0.540 N. Then $|q_1|$ is doubled, $|q_2|$ is tripled, and distance is tripled. The signs stay the same. What is the new magnitude, and does the force change between attraction and repulsion?

Work:

Final answer (with unit and sign): _____

Challenging · B2-P10. Sample data for fixed charges are: at r = 0.100 m, F = 0.800 N; at 0.200 m, F = 0.200 N; at 0.400 m, F = 0.0500 N. Draw a straightened graph with labelled axes and units, plot all three points, find its slope, and predict F at 0.300 m.

Work:

Final answer (with unit and sign): _____

B2 · Practice

Coulomb’s law | Questions 11-12 of 12

Challenging · B2-P11. A student uses $q_1 = +2.00\ \mu C$, $q_2 = -6.00\ \mu C$ and $r = 0.300$ m, then reports “$F = -1.20$ N, so the force on the right-hand charge points left.” Say which part is right and which part is wrong. What is the correct magnitude and force direction on each charge? Use $k = 8.99 \times 10^9\ N \cdot m^2/C^2$; q_1 is on the left.

Work:

Final answer (with unit and sign): _____

Challenging · B2-P12. You can vary distance between two small charged spheres and measure force. What should remain fixed to test the distance relationship? Choose at least three distances, predict the force ratios for r, 2r and 3r, name a suitable graph, and explain one role shared by the Coulomb and Cavendish torsion balances.

Work:

Final answer (with unit and sign): _____