B1 · Charge and charging

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

Explain charge, draw charge separation, and predict the result of contact or grounding.

Name: _____ Date: _____

Slide 1 of 8 · Charge is carried by electrons

A rubbed balloon sticks to a wall. Unit B explains why. We start with what carries charge.

Atoms have _____ (+) in the nucleus and _____ (−) around it. One electron has charge size e = _____. C is the _____, the unit of charge.

Neutral: _____ protons and electrons, so the charges cancel. Only _____ move; protons stay in the nucleus.

Gain electrons: _____. Lose electrons: _____. Charge is _____: it moves, and is never made or lost.

Charge comes in whole electrons: Q = _____. n is a count, with no sign. Find the size, then add the _____.

Example. A neutral plastic rod is rubbed with wool and gains 2.5×10^{13} electrons from the cloth. What is the charge on the rod, with its sign? Use $e = 1.60 \times 10^{-19}$ C.

Work:

Answer: _____

Try it. A glass rod is rubbed with silk and ends with a charge of +3.2 μC. How many electrons did the glass rod lose, and where did they go?

Work:

Answer: _____

Slide 2 of 8 · Conductors, insulators and rubbing

On slide 1, only electrons moved. Where they can move depends on the material.

In a metal, some outer electrons are _____ and roam the whole object. Metals are _____. In plastic, glass, rubber and wool, electrons stay with their atoms. These are _____.

Extra electrons repel each other. On a metal they _____. On plastic they stay _____.

Rubbing moves electrons, because materials hold electrons with different strengths. The weaker holder loses electrons and turns _____. The other turns _____ by the _____.

On the diploma, explain a result by saying which way the _____ moved.

Example. A plastic ruler is rubbed with a wool cloth and the ruler becomes negative. No protons moved. What is the sign of the charge on the wool, how do the two sizes compare, and which material holds electrons more strongly?

Work:

Answer: _____

Try it. A student rubs a metal rod with a cloth while holding the rod in a bare hand. Brought near bits of paper, it does nothing. Explain why, and say what could be changed so the rod keeps its charge.

Work:

Answer: _____

Slide 3 of 8 · Why a neutral object is attracted

A charged rod also pulls on objects that have no charge. Slide 2 helps explain why.

A negative rod near a neutral metal sphere: like charges repel, so free electrons move to the _____ side. The near side is short of electrons, so it is _____.

This shift is charge _____. It ends when the rod leaves. The sphere is still _____. No electrons left it.

Unlike charges attract, and the near side is _____, so attraction is _____. The sphere is pulled toward the rod.

Attraction alone _____ prove an object is charged. Only _____ proves it.

Example. A negative rod is held near, but not touching, a neutral metal sphere on an insulating stand. What is the sign of the charge on the side nearest the rod, what is the total charge of the sphere, and does the sphere move toward or away from the rod?

Work:

Answer: _____

Try it. A charged rod attracts a small object hanging from a thread. Which statement must be true? A. The object has a charge opposite to the rod. B. The object is neutral. C. The object may be neutral or have a charge opposite to the rod. D. The object has the same charge as the rod.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 4 of 8 · Charging by contact and sharing

So far the rod only came near an object. Now two metal spheres touch.

Touching conductors share charge. If the stands are _____, no charge can enter or leave, so the _____ stays the same.

Identical spheres (same size and shape) end with _____ charge: q = _____.

Add the charges _____ first, then divide by two. The final sign is the sign of _____.

Sketch the problem three times: _____, _____ and _____, with each charge written beside its sphere. Check that the total after equals the total _____.

Example. Two identical metal spheres carry +7.0 µC and −3.0 µC. They touch and are then separated. What is the charge on each sphere after the separation?

Work:

Answer: _____

Try it. Three identical spheres A, B and C carry +9.0 µC, 0 and −3.0 µC. A touches B and they separate. Then B touches C and they separate. What is the final charge on each of A, B and C?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 5 of 8 · Method: how to find the charge after spheres touch

These are the steps you used on slide 4.

Step 1: write each charge _____. Step 2: _____ the signed charges. Step 3: divide by the _____.

Step 4: give _____ that charge, with its sign. Step 5: check that the total after is _____ the total before.

Example. Two identical metal spheres carry +7.0 µC and −3.0 µC. They touch and are then separated. Use the five steps to find the charge on each sphere.

Work:

Answer: _____

Try it. NEW, for teacher review: Two identical spheres carry +5.0 µC and −9.0 µC. They touch and are separated. What is the charge on each sphere?

Work:

Answer: _____

Slide 6 of 8 · Grounding and induction

On slide 3 the shift ended when the rod left. A path to the Earth lets the sphere keep a charge.

The Earth is so large that it can give or take any number of electrons and stay neutral. A wire or conducting path to the Earth is called a _____.

Induction means charging an object _____ with the charged object. Steps in order: 1. bring the rod _____; 2. connect the _____; 3. remove the _____ wire; 4. remove the _____.

A negative rod pushes electrons away, so they leave through the ground and the sphere ends _____. A positive rod pulls electrons up from the ground and the sphere ends _____.

Contact gives the _____ sign as the rod. Induction gives the _____ sign. The shift while the rod is near is charge _____; the charge left is _____ charge. Remove the ground wire first so the charge is trapped; if the rod leaves first, electrons _____.

Example. A positive rod is brought near, but never touches, a neutral metal sphere on an insulating stand. The sphere is grounded with a wire. The ground wire is removed first, and then the rod. What is the sign of the charge left on the sphere, and where did the charge come from?

Work:

Answer: _____

Try it. A neutral metal sphere on an insulating stand is to be given a positive charge using a negative rod. Which option does this? A. Touch the rod to the sphere, then remove the rod. B. Rod near, connect ground, remove rod, remove ground. C. Rod near, connect ground, remove ground, remove rod. D. Rod near, remove rod, connect ground.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 7 of 8 · The electroscope

We cannot see electrons shift inside a metal. This tool shows it.

An electroscope is a metal _____ joined by a metal rod to two thin metal _____. Electrons can move between the knob and the leaves. When it is neutral the leaves hang _____.

A negative rod near the knob pushes electrons _____ to the leaves. Both leaves are _____, so they _____ and spread apart. A positive rod pulls electrons _____, so both leaves are _____ and they spread apart too.

A neutral electroscope shows that a charge is _____. It cannot show the _____. Touch the knob with a charged rod and the leaves _____: charging by contact. Touch the knob with a finger and the leaves _____: it is grounded.

On a charged electroscope, an object with the _____ sign makes the leaves spread more. An object with the _____ sign makes them move closer together.

Example. An electroscope has been charged negative by contact, so its leaves stand apart. Charged object X is held near the knob, without touching it, and the leaves move farther apart. X is taken away. Charged object Y is held near the knob, without touching it, and the leaves move closer together. What is the sign of the charge on X, and on Y? Explain each answer with the movement of electrons.

Work:

Answer: _____

Try it. NEW, for teacher review: An electroscope has been charged positive by contact, so its leaves stand apart. Charged object Z is held near the knob, without touching it, and the leaves move farther apart. What is the sign of the charge on Z? Explain with the movement of electrons.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 8 of 8 · Method: how to explain a charging result in words

Use these steps for any “explain the charge” question in this lesson.

Step 1: name the object and say whether it is a _____. Step 2: say which way the _____ move. Step 3: say what each object _____.

Step 4: state the final sign. Gaining electrons gives _____; losing electrons gives _____. Step 5: say the total charge _____.

Example. A positive rod is brought near a neutral metal sphere on an insulating stand. The sphere is grounded, the ground is removed, and then the rod is removed. Explain the final charge on the sphere.

Work:

Answer: _____

Try it. NEW, for teacher review: A neutral metal sphere on an insulating stand touches a negative rod. Explain the sign of the charge on the sphere.

Work:

Answer: _____

B1 · Practice

Charge and charging | Questions 1-2 of 12

Use $k = 8.99 \times 10^9$ N·m²/C² and $g = 9.81$ m/s² where needed. These values are from the Alberta Physics 30 data sheets, Constants section. All point-charge calculations approximate air as vacuum.

Easy · B1-P01. An object has 8 protons and 10 electrons, each with a charge of the same size. What is the object's total charge in units of e, and what electron change would make it neutral?

Work:

Final answer (with unit and sign): _____

Easy · B1-P02. A neutral metal sphere loses electrons to another object. What is its final sign? Describe the change in the total charge of the two objects together.

Work:

Final answer (with unit and sign): _____

B1 · Practice

Charge and charging | Questions 3-4 of 12

Easy · B1-P03. Extra charge spreads across a metal object but stays near the rubbed spot on a plastic object. Which is the conductor and which is the insulator? Explain using charge motion.

Work:

Final answer (with unit and sign): _____

Easy · B1-P04. A known negative object repels a small charged object. What is the sign of the small object? If the observation were attraction instead, could you be certain it was positive? Explain.

Work:

Final answer (with unit and sign): _____

B1 · Practice

Charge and charging | Questions 5-6 of 12

Medium · B1-P05. A positive rod approaches the left side of a neutral metal sphere on an insulating stand without contact. Draw the sphere’s near-side and far-side charge signs, the electron-motion arrow, and its total charge. Explain the attraction.

Optional start: Track electrons first. Did any enter or leave the sphere?

Work:

Final answer (with unit and sign): _____

Medium · B1-P06. Two identical metal spheres on insulating supports have +8.0 µC and −2.0 µC. They touch and are separated far apart. No charge escapes. What is each final charge, and which way did electrons move?

Optional start: Add signed charges before dividing.

Work:

Final answer (with unit and sign): _____

B1 · Practice

Charge and charging | Questions 7-8 of 12

Medium · B1-P07. A negative rod is held near a neutral metal sphere. The sphere is grounded, the ground is disconnected, and then the rod is removed. What is the final sign? Draw the electron path during grounding and explain the order.

Work:

Final answer (with unit and sign): _____

Medium · B1-P08. A positive rod is brought near a neutral metal sphere on an insulating stand, then removed. There is no contact or grounding. What are the sphere’s total charge while the rod is near and after it leaves? Explain where the charges sit at both times.

Work:

Final answer (with unit and sign): _____

B1 · Practice

Charge and charging | Questions 9-10 of 12

Challenging · B1-P09. Sphere A starts at +10.0 μC, sphere B at −4.0 μC and sphere C at 0 μC. All are identical metal spheres on insulating supports. A touches B, then they separate far apart. B then touches C and they separate far apart. No charge escapes. What is each final charge? Check the total.

Work:

Final answer (with unit and sign): _____

Challenging · B1-P10. A student charges a sphere using a negative rod and ground, but removes the rod while the ground wire is still attached. The rod is moved far away before the ground is disconnected. What is the final charge? Explain why this differs from the correct induction sequence.

Work:

Final answer (with unit and sign): _____

B1 · Practice

Charge and charging | Questions 11-12 of 12

Challenging · B1-P11. A student says, “A neutral plastic comb cannot be attracted to a charged rod because electrons cannot move freely through plastic.” Identify the error. Draw or describe what the charges inside the comb do to explain the attraction without giving the comb a total charge.

Work:

Final answer (with unit and sign): _____

Challenging · B1-P12. Two metal objects of different sizes with charges +8.0 µC and −2.0 µC touch, and no charge can enter or leave. A student predicts +3.0 µC on each. Which part of the prediction is guaranteed, which is not, and what extra condition would justify equal sharing?

Work:

Final answer (with unit and sign): _____

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): _____

B3 · Net electric force

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

Add force vectors on one target and choose between a charge model and force balance.

Name: _____ Date: _____

Slide 1 of 5 · One target, several sources

B2 found the force between two charges. Most real cases have more than two. This lesson adds the forces on one charge.

Pick one charge as the _____. Every other charge is a _____. Find the force on the target from _____. The sum of the separate forces is the _____.

Coulomb's law F = _____ gives the _____ only, with k = _____. The direction comes from the signs: _____ charges push apart, _____ charges pull together.

Draw an arrow for each force first. Choose east as _____. An arrow east counts as _____ and an arrow west counts as _____. Add the forces _____. The sign of the net force gives its direction.

The distance r always runs from the _____ to the _____. If the target is outside the pair of sources, measure a _____ for each source. Label every position in a sketch before you calculate.

Example. A is +4.0 µC at x = 0, the target B is +2.0 µC at x = 0.30 m, and C is +3.0 µC at x = 0.50 m. East is positive. What is the net force on B, with its direction?

Work:

Answer: _____

Try it. Same positions, but C is now −3.0 µC. A is +4.0 µC at x = 0, the target B is +2.0 µC at x = 0.30 m, and C is at x = 0.50 m. What is the net force on B, with its direction?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 2 of 5 · Forces at right angles

Slide 1 had forces on one line. Now two forces meet at a right angle.

A coordinate pair such as (0.30 m, 0) means _____. East is the positive x direction and _____ is the positive y direction.

Find each force with Coulomb's law, and decide each direction from the signs. Draw both arrows _____. If the two forces are at _____, draw a right triangle with the arrows as its sides.

The net force is the _____: F = _____. The angle comes from tan θ = _____, so θ = _____.

A direction needs an angle and a _____, such as "36.9° north of west". If the forces are at 90°, the net force is bigger than _____ but smaller than their _____.

Example. The target (+2.0 μC) is at the origin (0, 0). A +3.0 μC charge is at (0.30 m, 0) and a −4.0 μC charge is at (0, 0.40 m). What is the net force on the target, with its direction?

Work:

Answer: _____

Try it. Same positions, but the charge at (0.30 m, 0) is −3.0 μC and the charge at (0, 0.40 m) is +4.0 μC. The target is still +2.0 μC. What is the net force on the target, with its direction?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 3 of 5 · Method: how to find the net force on one charge

These are the steps you used on slides 1 and 2, in one place.

Step 1, _____: sketch the target and every source. Label each charge and each _____.

Step 2, _____: for each source, F = _____, using the _____ of the charges only. Step 3, _____: alike charges push the target _____; unlike charges pull it _____ the source.

Step 4, _____: write each force as an _____ and a _____. East and north are _____; west and south are _____. Step 5, _____: add all the x parts, then add all the _____.

Step 6, _____: size = _____; angle = _____. Name the direction from a _____, such as “north of west”.

Example. Use the six steps. The target (+2.0 µC) is at (0, 0). A +3.0 µC charge is at (0.30 m, 0) and a −4.0 µC charge is at (0, 0.40 m).

Work:

Answer: _____

Try it. Use the six steps. The target (+1.0 µC) is at (0, 0). A +2.0 µC charge is at (0.20 m, 0) and a +3.0 µC charge is at (0, 0.30 m). Find the net force, with its direction.

Work:

Answer: _____

Slide 4 of 5 · A force along a diagonal

On slide 2 each force lay along an axis. Now a force points along a slant.

A source at (0.30 m, 0.40 m) is 0.30 m east and 0.40 m north of a target at the origin. The straight-line distance is r = _____. The force acts along this _____.

Find the size first with Coulomb's law. Alike charges push the target _____ from the source and unlike charges pull it toward the source. The target is pushed away, so a source to the north-east pushes the target _____.

A _____ is one part of a force along one axis. The force triangle has the _____ as the distance triangle, so component = force × (_____ ÷ _____). Each component is _____ than the force.

To add several forces, make two sums: one for _____ and one for _____. East and north count as _____; west and south count as _____. Then use _____ for the size and tan θ for the angle.

Example. The target (+1.0 µC) is at the origin and a +5.0 µC source is at (0.30 m, 0.40 m). What is the force on the target, and what are its east-west and north-south parts, with directions?

Work:

Answer: _____

Try it. The +1.0 µC target is at the origin and the +5.0 µC source is at (0.30 m, 0.40 m). A second source of −2.0 µC is added at (0, 0.20 m). What is the net force on the target, with its direction?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 5 of 5 · A charge hanging at rest

So far every force was electric. Now gravity and a thread pull as well.

Weight W = _____, with g = _____: each kilogram weighs 9.81 N. T is the _____, the pull of the thread. F_e is the _____, which is horizontal.

At rest the net force is _____. The three force arrows close into a _____. Draw the weight straight _____, the tension along the _____ and the electric force _____.

In the triangle, θ is the angle between the weight and the _____. F_e is _____ θ and mg is adjacent to θ: tan θ = _____, so F_e = _____.

The angle θ is measured from the _____. F_e is _____ the angle and mg is _____ to it, so use _____, not sine or cosine. For two equal charges, Coulomb's law then gives q = _____.

Example. A sphere of mass 0.0100 kg hangs from a thread at 20.0° from the vertical, pushed sideways by a fixed charge 0.15 m away. Find the electric force. If the two charges are equal, find each charge.

Work:

Answer: _____

Try it. A sphere of mass 0.0200 kg hangs from a thread and is pushed sideways by a fixed charge so that the thread makes 30.0° with the vertical. The sphere is at rest. What is the size of the electric force on the sphere? Use g = 9.81 m/s².

Work:

Answer: _____

Sketch (draw and label the diagram):

B3 · Practice

Net electric force | Questions 1-2 of 12

Use $k = 8.99 \times 10^9$ N·m²/C² and $g = 9.81$ m/s² where needed. These values are from the Alberta Physics 30 data sheets, Constants section. All point-charge calculations approximate air as vacuum.

Easy · B3-P01. A is positive and left of a negative target B. C is negative and right of B. Draw the two force arrows on B. Do the forces add or partly cancel? Explain each arrow.

Work:

Final answer (with unit and sign): _____

Easy · B3-P02. The forces on one charge are 0.600 N right and 0.250 N left. Choose right as positive. What are the signed components and the net force?

Work:

Final answer (with unit and sign): _____

B3 · Practice

Net electric force | Questions 3-4 of 12

Easy · B3-P03. A target feels 0.400 N east and 0.400 N west. What is its net force? Does that mean neither source exerts a force? Explain.

Work:

Final answer (with unit and sign): _____

Easy · B3-P04. A charged sphere is at rest with its string tilted from vertical by a horizontal electric force. Describe the weight, tension and electric-force arrows. Why must the tension not be drawn vertically?

Work:

Final answer (with unit and sign): _____

B3 · Practice

Net electric force | Questions 5-6 of 12

Medium · B3-P05. Point charges in air are A = +3.00 μC at x = 0, target B = −1.00 μC at x = 0.300 m and C = +1.00 μC at x = 0.600 m. What is the net force on B? Use $k = 8.99 \times 10^9$ N·m²/C².

Optional start: Calculate two pair forces; do not add source charges first.

Work:

Final answer (with unit and sign): _____

Medium · B3-P06. The calculated electric forces on a target are 0.500 N east and 0.200 N north. Draw a vector triangle. What are the size of the net force and its angle north of east?

Work:

Final answer (with unit and sign): _____

B3 · Practice

Net electric force | Questions 7-8 of 12

Medium · B3-P07. A 4.00×10^{-4} kg charged sphere hangs at rest. Its string is 25.0° from vertical and the electric force acts horizontally right. What are the electric-force magnitude and the tension? Use $g = 9.81$ m/s².

Optional start: The vertical component uses cosine because the angle is from vertical.

Work:

Final answer (with unit and sign): _____

Medium · B3-P08. Case A gives two point charges and their distance. Case B gives a hanging sphere’s mass and string angle from vertical, with a horizontal electric force. Choose a method to find electric force in each case. Explain why the other method cannot be used directly from the givens.

Work:

Final answer (with unit and sign): _____

B3 · Practice

Net electric force | Questions 9-10 of 12

Challenging · B3-P09. Point charges in air are target P = +1.00 μC at (0,0), A = +2.00 μC at (−0.300 m,0), and C = +1.00 μC at (0,+0.300 m). What is the net electric force on P, as a magnitude and direction? Use $k = 8.99 \times 10^9$ N·m²/C².

Work:

Final answer (with unit and sign): _____

Challenging · B3-P10. A charged sphere hangs at rest in a horizontal electric force of 3.00×10^{-3} N. Its mass is 5.00×10^{-4} kg. What is the string's angle from vertical and what is the tension? Use g = 9.81 m/s².

Work:

Final answer (with unit and sign): _____

B3 · Practice

Net electric force | Questions 11-12 of 12

Challenging · B3-P11. Two sources exert electric forces of 0.600 N east and 0.800 N north on a target. A student reports 1.40 N northeast. Find the correct magnitude and direction. Explain exactly what the student’s addition assumes incorrectly.

Work:

Final answer (with unit and sign): _____

Challenging · B3-P12. A = +2.00 μC is at x = 0 and C = +8.00 μC is at x = 0.900 m. A positive target charge is placed somewhere between them. Where is the net electric force zero? Give its distance from A and explain why the target’s charge magnitude is not needed.

Work:

Final answer (with unit and sign): _____

B4 · Electric fields

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

Distinguish field from force, map field directions and combine source fields.

Name: _____ Date: _____

Slide 1 of 6 · Field means force per charge

In B2 and B3, one charge pushed another across empty space. A field explains how.

A charge can push another charge across empty space. It does this with a _____. A small test charge, _____, feels a force F. Double q_test and F _____.

So divide out the charge: E = _____, the force per unit charge, in _____.

E points the way a _____ test charge is pushed. A negative charge is pushed the _____ way.

F = _____. The size of q gives the size of F. The _____ gives the direction.

Convert μC to _____: multiply by _____. Keep extra digits and round _____, at the end.

Example. A +5.00 μC test charge feels a force of 0.0150 N south at a point. What are the size and direction of the electric field at the point?

Work:

Answer: _____

Try it. An electron ($e = 1.60 \times 10^{-19}$ C) is placed at a point where the electric field is 500 N/C north. What are the size and direction of the force on the electron?

Work:

Answer: _____

Slide 2 of 6 · The field of a point charge

Slide 1 defined the field. Now find it for a point charge.

A point source _____ makes a field. r is the distance from the _____. Coulomb's law gives $F = k|Q|q_{test}/r^2$. Divide by q_{test} and it _____.

E = _____, with k = _____.

The field depends on the _____ and the _____, not on the test charge. Double r: the field is _____.

Positive source: the field points _____. Negative source: _____. Use $|Q|$ in the formula. The sign gives _____ only.

Convert prefixes first: μ = _____, n = _____. The distance must be in _____.

Example. A source of +4.0 μC is 0.30 m from point P. Use $k = 8.99 \times 10^9$ N·m²/C². What are the size and direction of the electric field at P?

Work:

Answer: _____

Try it. A source of −2.0 nC (that is, -2.0×10^{-9} C) is 0.050 m from point P. What are the size and direction of the electric field at P?

Work:

Answer: _____

Slide 3 of 6 · From field to force to acceleration

Slides 1 and 2 gave the field. Now use it to find how a particle moves.

Field gives _____, and force gives _____. Here q is the particle's _____ charge, not the test charge.

Force: F = _____. Only the electric force acts, so this is the net force.

Acceleration: a = _____, so a = _____. Do the force on its own line first.

The force points _____ the field for a positive charge and _____ it for a negative charge. A uniform field has the _____ everywhere.

An electron has mass _____. Its weight is about 10^{13} times smaller than this force, so gravity is _____.

Example. An electron ($q = -1.60 \times 10^{-19}$ C, $m = 9.11 \times 10^{-31}$ kg) is placed in a uniform electric field of 2.50×10^{3} N/C north. Only the electric force acts. What are the size and direction of the electron's acceleration?

Work:

Answer: _____

Try it. A proton ($q = +1.60 \times 10^{-19}$ C, $m = 1.67 \times 10^{-27}$ kg) is placed in a uniform electric field of 2.50×10^{3} N/C north. Only the electric force acts. What are the size and direction of the proton's acceleration?

Work:

Answer: _____

Slide 4 of 6 · Method: how to go from field to force to acceleration

These are the steps you used on slide 3.

Step 1: _____ the field E. Use the given field, or E = _____ for a point source, with the size of Q.

Step 2: name the _____ of E: away from a _____ source and toward a _____ source.

Step 3: find the force with F = _____. Here q is the charge placed in the field, not the test charge. Use its _____.

Step 4: name the direction of F: the _____ E if q is positive and _____ E if q is negative.

Step 5: find the acceleration with a = _____, in the direction of _____.

Check: the answer has units of _____ and its direction matches the _____ of q.

Example. An electron ($q = -1.60 \times 10^{-19}$ C, $m = 9.11 \times 10^{-31}$ kg) is placed in a uniform electric field of 2.50×10^{3} N/C north. Only the electric force acts. What are the size and direction of the electron's acceleration?

Work:

Answer: _____

Try it. A source of +3.0 µC makes the field at a point 0.30 m away. A −2.0 µC charge of mass 0.0040 kg is placed there. What are the size and direction of its acceleration? Only the electric force acts.

Work:

Answer: _____

Slide 5 of 6 · Adding fields from several sources

So far one source made the field. Now there are two.

Two sources make two fields. Add them as _____. The sum is the _____.

Find each field with E = _____. Mark each direction at the point. Then add. On a line, call one direction _____.

Arrows the same way: the sizes _____. Opposite ways: the sizes _____. At right angles: size = _____, tan θ = _____.

Field lines: 1. draw the charges and mark their _____; 2. start on a _____ charge, end on a _____ one; 3. put lines _____ where the field is strong; 4. add an _____ on every line.

Lines never _____. Between large parallel plates the lines are straight and _____: a _____ field.

Example. Two sources, +2.0 μC at x = 0 and −2.0 μC at x = 0.40 m. Point P is midway between them, 0.20 m from each. Draw the field arrows at P, then find the size and direction of the net field at P.

Work:

Answer: _____

Try it. Two equal positive point charges are placed on a horizontal line, and point P is midway between them. Which statement about the field at P is correct? A. It is zero. B. It is directed toward the left charge. C. It is directed toward the right charge. D. It is twice the field of one charge.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 6 of 6 · Method: how to add fields from several sources

These are the steps you used on slide 5.

Step 1: _____ the point and every source, with each source's sign and its distance from the point.

Step 2: find the size of each field on its own with E = _____.

Step 3: draw each arrow starting at the point, _____ a positive source and _____ a negative source.

Step 4: _____ each arrow into x and y parts. Choose a positive direction for each axis and give each part a + or − sign.

Step 5: add all the _____ parts to get Ex and all the _____ parts to get Ey.

Step 6: E = _____. Name the direction from a _____, such as east.

Check: the net arrow on the drawing points the _____ as your answer.

Example. Two sources, +2.0 µC at x = 0 and −2.0 µC at x = 0.40 m. Point P is midway between them, 0.20 m from each. East is positive. Find the size and direction of the net field at P.

Work:

Answer: _____

Try it. Two sources, +4.0 µC at x = 0 and +1.0 µC at x = 0.60 m. East is positive. Point P is 0.20 m from the +4.0 µC source, on the line between the sources. Find the size and direction of the net field at P.

Work:

Answer: _____

B4 · Practice

Electric fields | Questions 1-2 of 12

Use $k = 8.99 \times 10^9$ N·m²/C² and $g = 9.81$ m/s² where needed. These values are from the Alberta Physics 30 data sheets, Constants section. All point-charge calculations approximate air as vacuum.

Easy · B4-P01. A fixed source creates a field at P. A small positive test charge q_test is replaced by a test charge +2q_test and the source does not change. What happens to the field at P and to the force on the test charge? Explain using the definition of field.

Work:

Final answer (with unit and sign): _____

Easy · B4-P02. A point source is positive. At a point to its left, draw the electric-field arrow. Then draw the force arrow on a negative test charge placed there. Explain both directions.

Work:

Final answer (with unit and sign): _____

B4 · Practice

Electric fields | Questions 3-4 of 12

Easy · B4-P03. A +4.00 µC test charge feels 0.0800 N east in an electric field. What is the field strength and direction at that point?

Work:

Final answer (with unit and sign): _____

Easy · B4-P04. Between large horizontal plates the electric field points up. Ignore the edges of the plates. Which plate is positive, which is negative, and which way is the electric force on an electron? Does the field strength change between two points inside?

Work:

Final answer (with unit and sign): _____

B4 · Practice

Electric fields | Questions 5-6 of 12

Medium · B4-P05. A point source $Q = -4.00\ \mu C$ is fixed in air. P is 0.200 m to its right. What is the electric field at P? Use $k = 8.99 \times 10^9\ N \cdot m^2/C^2$.

Work:

Final answer (with unit and sign): _____

Medium · B4-P06. A charge $q = -3.00\ nC$ is placed in a field of $4.00 \times 10^4\ N/C$ west. What is the electric force on it? Does its negative sign reverse the field itself?

Optional start: Separate the magnitude calculation from the negative-charge direction.

Work:

Final answer (with unit and sign): _____

B4 · Practice

Electric fields | Questions 7-8 of 12

Medium · B4-P07. At P, a +2.00 μC source is 0.300 m to the left and a −1.00 μC source is 0.300 m to the right. What is the net electric field at P? Use $k = 8.99 \times 10^9$ N·m²/C².

Work:

Final answer (with unit and sign): _____

Medium · B4-P08. A source is at (0,0). A field map shows E at (0.200 m,0) pointing right with strength 4.00×10^5 N/C. The source stays fixed. What is its sign? Predict the field magnitude and direction at (0.400 m,0) and at (−0.200 m,0).

Work:

Final answer (with unit and sign): _____

B4 · Practice

Electric fields | Questions 9-10 of 12

Challenging · B4-P09. Point sources A = +1.00 µC at (−0.300 m,0) and C = −2.00 µC at (0,+0.300 m) create a field at P = (0,0). What are the net field magnitude and direction? Use $k = 8.99 \times 10^9$ N·m²/C².

Work:

Final answer (with unit and sign): _____

Challenging · B4-P10. A point has an electric field of 6.00×10^4 N/C east. A small unknown charge feels 0.120 N west. What are the charge's magnitude and sign? Explain how the directions determine the sign.

Work:

Final answer (with unit and sign): _____

B4 · Practice

Electric fields | Questions 11-12 of 12

Challenging · B4-P11. Two equal sources are fixed on a horizontal line. Compare the field at the midpoint for (a) two positive sources and (b) a positive source on the left and an equal negative source on the right. Then describe field-line sketches for both pairs: add arrows and explain whether lines cross.

Work:

Final answer (with unit and sign): _____

Challenging · B4-P12. Mixed review: two identical metal spheres on insulating stands start with +6.00 µC and −2.00 µC, touch, then separate far apart. Afterwards one sphere is held fixed as a point source; the other is moved far enough away that its field at P is too small to matter. P is 0.300 m right of the fixed sphere. What field is at P, and what force acts on a −2.00 nC charge there? Use $k = 8.99 \times 10^9$ N·m²/C².

Work:

Final answer (with unit and sign): _____