Source of Charge

- An atom
  - ____________
    - Protons – ____________ charge
    - Neutrons – ____________ charge, but same ____________ as proton
  - Electron cloud
    - Electron – ____________ charge, ____________ mass
    - $q_e = -1.60 \times 10^{-19}\ C$
- Unit of charge: ____________ (C)
- q_e is the ____________ charge discovered
- Electricity is ____________ → comes in ____________ numbers
- $|q_e|$ is the ______________ unit of charge
- In nature atoms have ____________ net charge
  - # ____________ = # ____________

How many electrons does it take to make a charge of $-4 \times 10^{-6}\ C$? What is their mass ($m_e = 9.11 \times 10^{-31}\ kg$)?

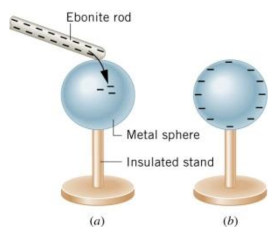
Law of Conservation of Charge
During any process, the net ____________ ____________ of a ____________ system remains ____________

- Like charges ____________
- Unlike charges ____________
  - The attraction and repulsion are ____________ and can be used with ____________ Laws and other dynamics problems

Conductors and Insulators

- Electricity can flow ____________ objects
- Conductors let electrons flow ____________
  - Most ____________ conductors are also ____________ conductors
  - ____________
- Insulators are very poor conductors
  - ____________ ____________ ____________

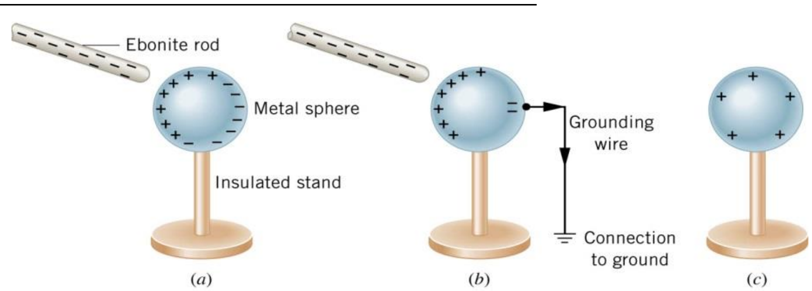
Charging by contact



- Negative charged rod gives some ____________ to sphere
- Sphere becomes ____________ charged until charges are ____________

Charging by Induction

- Charge without ____________
- Charged rod comes near ____________ sphere
- The like charges are ____________ to ____________ side of sphere
- A ____________ wire lets the charges ____________ from the sphere
- The ____________ wire is ____________, then the charged rod
- Sphere is ____________



- If the sphere was ____________ instead of metal
  - Electrons ____________ flow
  - The surface would become ____________ charged as the electrons in each individual atom rearrange, but no ____________ effect
  - ____________ cling is made by this ____________

Homework

1. There are very large numbers of charged particles in most objects. Why, then, don't most objects exhibit static electricity?
2. An eccentric inventor attempts to levitate by first placing a large negative charge on himself and then putting a large positive charge on the ceiling of his workshop. Instead, while attempting to place a large negative charge on himself, his clothes fly off. Explain.
3. When a glass rod is rubbed with silk, it becomes positive and the silk becomes negative—yet both attract dust. Does the dust have a third type of charge that is attracted to both positive and negative? Explain.
4. Describe how a positively charged object can be used to give another object a negative charge. What is the name of this process?
5. What is grounding? What effect does it have on a charged conductor? On a charged insulator?
6. A metallic object is given a positive charge by induction. (a) Does the mass of the object increase, decrease, or remain the same? Why? (b) What happens to the mass of the object if it is given a negative charge by induction?
7. Common static electricity involves charges ranging from nanocoulombs to microcoulombs. (a) How many electrons are needed to form a charge of –2.00 nC (b) How many electrons must be removed from a neutral object to leave a net charge of 0.500 μC? (OpenStax 18.1) $\mathbf{1.25 \times 10^{10}}$ **electrons,** $\mathbf{3.13 \times 10^{12}}$ **electrons**
8. If 1.80×10^{20} electrons move through a pocket calculator during a full day's operation, how many coulombs of charge moved through it? (OpenStax 18.2) **-28.8 C**
9. To start a car engine, the car battery moves 3.75×10^{21} electrons through the starter motor. How many coulombs of charge were moved? (OpenStax 18.3) **-600 C**
10. A certain lightning bolt moves 40.0 C of charge. How many fundamental units of charge $|q_e|$ is this? (OpenStax 18.4) $\mathbf{2.50 \times 10^{20}}$
11. Suppose a speck of dust in an electrostatic precipitator has 1.0000×10^{12} protons in it and has a net charge of –5.00 nC (a very large charge for a small speck). How many electrons does it have? (OpenStax 18.5) $\mathbf{1.03 \times 10^{12}}$
12. An amoeba has 1.00×10^{16} protons and a net charge of 0.300 pC. (a) How many fewer electrons are there than protons? (b) If you paired them up, what fraction of the protons would have no electrons? (OpenStax 18.6) $\mathbf{1.88 \times 10^{6}}$**,** $\mathbf{1.88 \times 10^{-10}}$
13. Consider three identical metal spheres, A, B, and C. Sphere A carries a charge of $+5q$. Sphere B carries a charge of $-q$. Sphere C carries no net charge. Spheres A and B are touched together and then separated. Sphere C is then touched to sphere A and separated from it. Last, sphere C is touched to sphere B and separated from it. (a) How much charge ends up on sphere C? What is the total charge on the three spheres (b) before they are allowed to touch each other and (c) after they have touched? (Cutnell 18.5) **1.5*q*, 4*q*, 4*q***

Coulomb's Law

- ___________ charges exert ___________ on each other
  - Related to the ___________ of the charges and the ___________ between them
- If the signs are ___________ force ___________
- If the signs are ___________ force ___________

Coulomb's Law

$$\boldsymbol{F = k\frac{|q_1 q_2|}{r^2}}$$

Where F = electrostatic force, k = constant (8.99×10^9 Nm²/C²), q = charge, r = distance between the charges

In a hydrogen atom, the electron ($q = -1.60 \times 10^{-19}$ C) is 5.29×10^{-11} m away from the proton of equal charge magnitude. Find the electrical force of attraction.

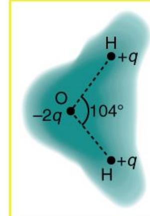
Force on 1 charge by 2 others

- Work in ___________ parts
  - Find ___________ of attraction by ___________ of the points
  - Find ___________ of attraction by the ___________ point
  - Add the force ___________
    - REMEMBER!!!!! You have to add the ___________ and ___________ ______________!!!!!

There are three charges in a straight line: $q_1 = +2\ \mu C$ at $x = -0.1$ m, $q_2 = -3\ \mu C$ at x = 0 m, $q_3 = +5\ \mu C$ at x = 0.3 m. What is the force on q_2?

There are three charges: $q_1 = +2\ \mu C$ at (0, 0.3) m, $q_2 = -3\ \mu C$ at (0, 0) m, $q_3 = +5\ \mu C$ at (0.1, 0.2) m. What is the force on q_2?

Homework



1. The figure shows the charge distribution in a water molecule, which is called a polar molecule because it has an inherent separation of charge. Given water's polar character, explain what effect humidity has on removing excess charge from objects.
2. A proton and an electron are held in place on the x axis. The proton is at $x = -d$, while the electron is at $x = +d$. They are released simultaneously, and the only force that affects their motions is the electrostatic force of attraction that each applies to the other. Which particle reaches the origin first? Give your reasoning.
3. Identical point charges are fixed to opposite corners of a square. Where does a third point charge experience the greater net force, at one of the empty corners or at the center of the square? Account for your answer.
4. What is the repulsive force between two pith balls that are 8.00 cm apart and have equal charges of – 30.0 nC? (OpenStax 18.10) $\mathbf{1.27 \times 10^{-3} N}$
5. (a) How strong is the attractive force between a glass rod with a 0.700 μC charge and a silk cloth with a –0.600 μC charge, which are 12.0 cm apart, using the approximation that they act like point charges? (b) Discuss how the answer to this problem might be affected if the charges are distributed over some area and do not act like point charges. (OpenStax 18.11) **0.263 N**
6. Two point charges exert a 5.00 N force on each other. What will the force become if the distance between them is increased by a factor of three? (OpenStax 18.12) **0.556 N**
7. Two point charges are brought closer together, increasing the force between them by a factor of 25. By what factor was their separation decreased? (OpenStax 18.13) **5 times**
8. How far apart must two point charges of 75.0 nC (typical of static electricity) be to have a force of 1.00 N between them? (OpenStax 18.14) **7.12 mm**
9. If two equal charges each of 1 C each are separated in air by a distance of 1 km, what is the magnitude of the force acting between them? You will see that even at a distance as large as 1 km, the repulsive force is substantial because 1 C is a very significant amount of charge. (OpenStax 18.15) $\mathbf{9 \times 10^{3}}$ **N**
10. A test charge of +2 μC is placed halfway between a charge of +6 μC and another of +4 μC separated by 10 cm. (a) What is the magnitude of the force on the test charge? (b) What is the direction of this force (away from or toward the +6 μC charge)? (OpenStax 18.16) **10 N, away from the 6 μC charge**
11. Bare free charges do not remain stationary when close together. To illustrate this, calculate the acceleration of two isolated protons separated by 2.00 nm (a typical distance between gas atoms). (OpenStax 18.17) $\mathbf{3.45 \times 10^{16}}$ **m/s²**
12. (a) Find the ratio of the electrostatic to gravitational force between two electrons. (b) What is this ratio for two protons? (c) Why is the ratio different for electrons and protons? (OpenStax 18.21) $\mathbf{4.16 \times 10^{42}}$**,** $\mathbf{1.24 \times 10^{36}}$

Electric Field

- We can use a ______________ charge to determine how the surrounding ______________ generate a ______________
    - Pick a small test charge so it doesn't ______________ the surrounding charge ________________

A test charge ($q_0 = 1.0 \times 10^{-10}\ C$) experiences a force of $2 \times 10^{-9}\ N$ when placed near a charged sphere. Determine the Force per Coulomb that the charge experiences and predict the force on a $2\ C$ charge.

Electric Field Definition

$$E = \frac{F}{q_0} = \frac{kq}{r^2}$$

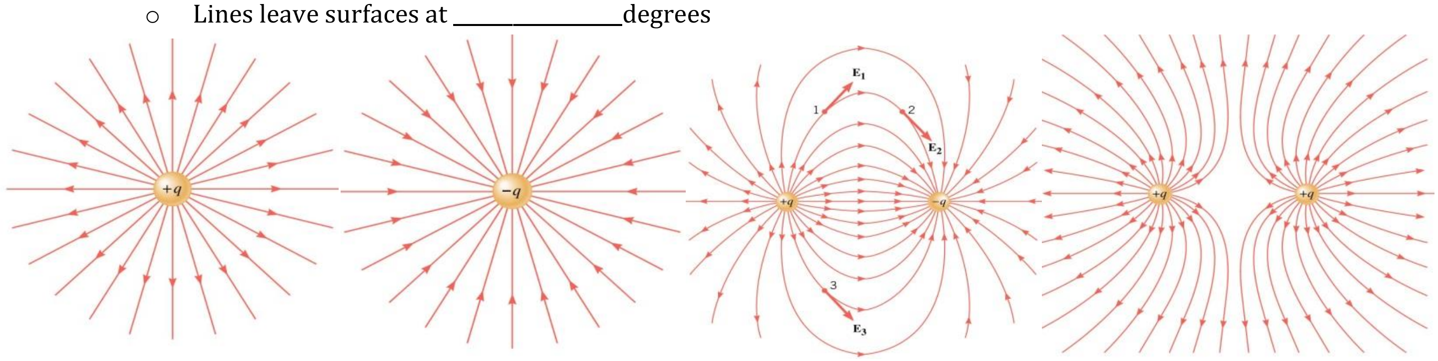
- ______________ per ______________
- Vector
    - Same ______________ as the force on a ______________ test charge
- Unit: N/C

There is a point charge of $q = 2 \times 10^{-8}\ C$. Determine the E-field at 0.50 m away using a test charge of $1 \times 10^{-10}\ C$.

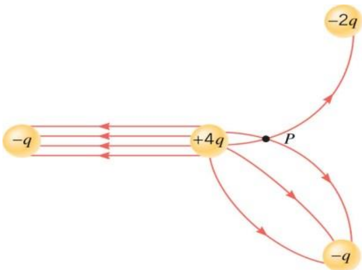
There are two point charges of $q_1 = 4\ C$ and $q_2 = 8\ C$ and they are 10 m apart. Find point where E = 0 between them.

Electric Field Lines

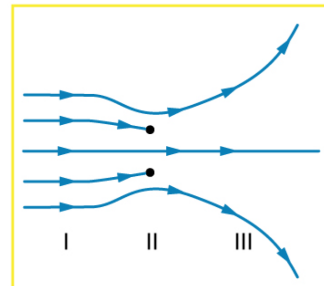
- Map to show the ______________ in ______________
- Rules
    - Lines begin at ______________ charges only
    - Lines end at ______________ charges only
    - The number of lines entering or leaving a charge is ________________ to the ______________ of charge
    - Lines don't ______________ each other
    - Lines leave surfaces at ______________degrees



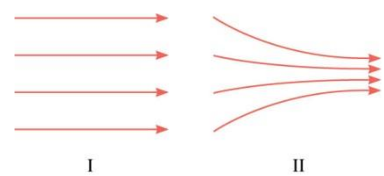
What is wrong here?



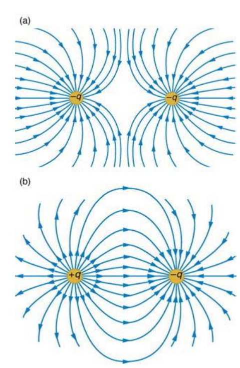
Homework

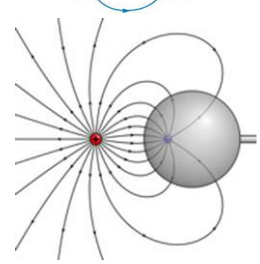


1. Why must the test charge q_0 in the definition of the electric field be vanishingly small?
2. The figure shows an electric field extending over three regions, labeled I, II, and III. Answer the following questions. (a) Are there any isolated charges? If so, in what region and what are their signs? (b) Where is the field strongest? (c) Where is it weakest? (d) Where is the field the most uniform?
3. There is an electric field at point P. A very small charge is placed at this point and experiences a force. Another very small charge is then placed at this point and experiences a force that differs in both magnitude and direction from that experienced by the first charge. How can these two different forces result from the single electric field that exists at point P?
4. Drawings I and II show two examples of electric field lines. Decide which of the following statements are true and which are false, defending your choice in each case. (a) In both I and II the electric field is the same everywhere. (b) As you move from left to right in each case, the electric field becomes stronger. (c) The electric field in I is the same everywhere but becomes stronger in II as you move from left to right. (d) The electric fields in both I and II could be created by negative charges located somewhere on the left and positive charges somewhere on the right. (e) Both I and II arise from a single positive point charge located somewhere on the left.

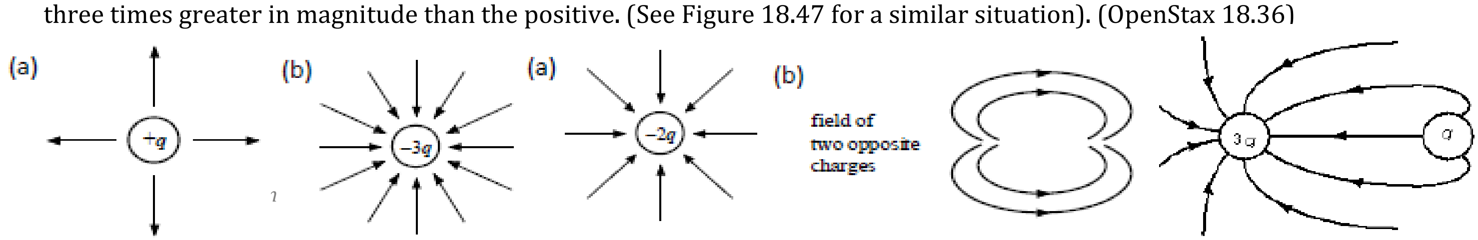


5. What is the magnitude and direction of an electric field that exerts a 2.00×10^{-5} N upward force on a –1.75 μC charge? (OpenStax 18.27) **-11.4 N/C downward**
6. What is the magnitude and direction of the force exerted on a 3.50 μC charge by a 250 N/C electric field that points due east? (OpenStax 18.28) $\mathbf{8.75 \times 10^{-4}}$ **N**
7. Calculate the magnitude of the electric field 2.00 m from a point charge of 5.00 mC (such as found on the terminal of a Van de Graaff). (OpenStax 18.29) $\mathbf{1.13 \times 10^{7}}$ **N/C**
8. (a) What magnitude point charge creates a 10,000 N/C electric field at a distance of 0.250 m? (b) How large is the field at 10.0 m? (OpenStax 18.30) $\mathbf{6.94 \times 10^{-8}}$ **C, 6.25 N/C**
9. (a) Find the direction and magnitude of an electric field that exerts a 4.80×10^{-17} N westward force on an electron. (b) What magnitude and direction force does this field exert on a proton? (OpenStax 18.32) **300 N/C east,** $\mathbf{4.80 \times 10^{-17}}$ **N east**
10. (a) Sketch the electric field lines near a point charge $+q$. (b) Do the same for a point charge $-3.00q$. (OpenStax 18.33) **see below**
11. Sketch the electric field lines a long distance from the charge distributions shown in Figure 18.26 (a) and (b) (OpenStax 18.34) **see below**



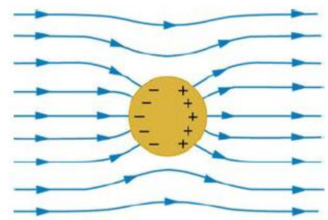


12. The figure shows the electric field lines near two charges q_1 and q_2. What is the ratio of their magnitudes? (b) Sketch the electric field lines a long distance from the charges shown in the figure. (OpenStax 18.35) **-1.9:1, like a point charge**
13. Sketch the electric field lines in the vicinity of two opposite charges, where the negative charge is three times greater in magnitude than the positive. (See Figure 18.47 for a similar situation). (OpenStax 18.36)

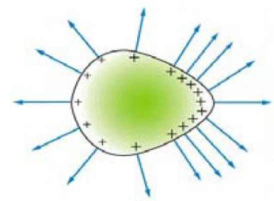


Conductors in Equilibrium

- Conductors contain ____________ charges that move ____________
- When ____________ charges are present, they quickly ____________ to places where the electric field is __________________ to the surface
- Then they ____________ moving
- This is electrostatic ____________



- Conductor in electric field will ____________
- Inside conductor, ____________
- Just outside of conductor, E-field is _________________ to ____________
- Any excess ____________ resides on ____________
- They get as far ____________ as ____________



- If the surface is ____________, more charge will collect near the area of most ____________
- If the curve is great enough, the E-field can be ____________ enough to ____________ excess charge

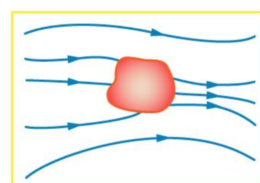
Shielding

- A conductor ____________ any charge ____________ it from ____________ electrical fields
- ____________ electrical equipment is ____________ by putting in a metal box called a ____________ Cage
- ____________ ____________ is shielded by a metal ____________ around the central metal wire. This reduces ________________ and ____________ ____________.

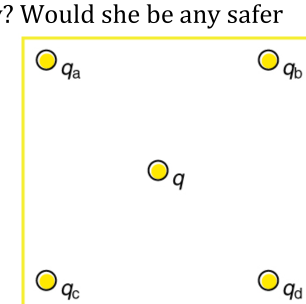
Applications

- Copy Machine
- Laser Printer
- Ink Jet Printer

Homework

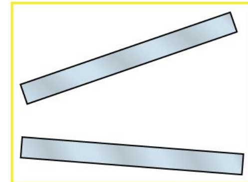


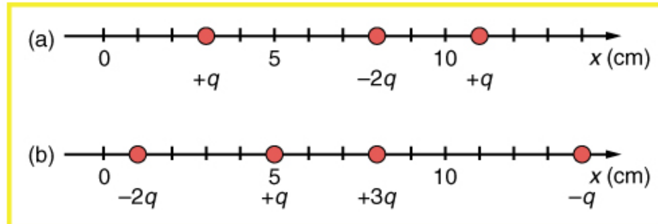
1. Is the object in the figure a conductor or an insulator? Justify your answer.
2. If the electric field lines in the figure above were perpendicular to the object, would it necessarily be a conductor? Explain.
3. Why is a golfer with a metal club over her shoulder vulnerable to lightning in an open fairway? Would she be any safer under a tree?
4. Are you relatively safe from lightning inside an automobile? Give two reasons.



5. Considering the figure, suppose that $q_a = q_d$ and $q_b = q_c$. First show that q is in static equilibrium. (You may neglect the gravitational force.) Then discuss whether the equilibrium is stable or unstable, noting that this may depend on the signs of the charges and the direction of displacement of q from the center of the square.
6. If $q_a = 0$ in the figure, under what conditions will there be no net Coulomb force on q?
7. Sketch the electric field lines in the vicinity of the conductor in the figure given the field was originally uniform and parallel to the object's long axis. Is the resulting field small near the long side of the object? (OpenStax 18.37) **See other side**

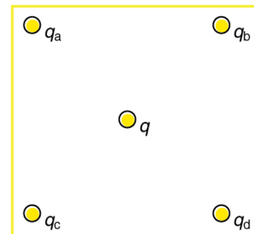
8. Sketch the electric field between the two conducting plates shown in the figure, given the top plate is positive and an equal amount of negative charge is on the bottom plate. Be certain to indicate the distribution of charge on the plates. (OpenStax 18.39) **See below**



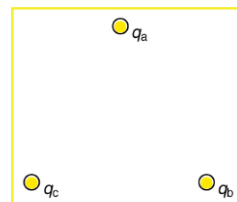


9. What is the force on the charge located at x = 8.00 cm in figure (a) given that q = 1.00 μC? (OpenStax 18.41) **12.8 N**

10. (a) Find the total electric field at x = 1.00 cm in figure (b) given that q = 5.00 nC. (b) Find the total electric field at x = 11.00 cm in figure (b). (c) If the charges are allowed to move and eventually be brought to rest by friction, what will the final charge configuration be? (That is, will there be a single charge, double charge, etc., and what will its value(s) be?) (OpenStax 18.42) $-\infty$, $\mathbf{2.12 \times 10^5}$ **N/C, +*q***

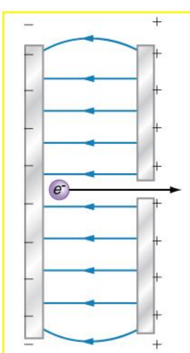


11. Using the symmetry of the arrangement, determine the direction of the force on q in the figure below, given that $q_a = q_b = +7.50\ \mu C$ and $q_c = q_d = -7.50\ \mu C$. (b) Calculate the magnitude of the force on the charge q, given that the square is 10.0 cm on a side and $q = 2.00\ \mu C$. (OpenStax 18.45) **down, 76.3 N downward**

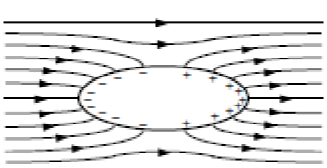


12. (a) Find the electric field at the location of q_a in the figure if it is an equilateral triangle with sides 25 cm, given that $q_b = +10.00\ \mu C$ and $q_c =- 5.00\ \mu C$. (b) What is the force on q_a, given that $q_a = +1.50\ nC$? (OpenStax 18.49) $\mathbf{1.25 \times 10^6}$ **N/C at 30° above the –x-axis,** $\mathbf{1.88 \times 10^{-3}}$ **N at 30° above the –x-axis**

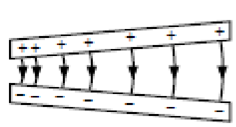
13. A simple and common technique for accelerating electrons is shown in the figure, where there is a uniform electric field between two plates. Electrons are released, usually from a hot filament, near the negative plate, and there is a small hole in the positive plate that allows the electrons to continue moving. (a) Calculate the acceleration of the electron if the field strength is 2.50×10^4 N/C. (b) Explain why the electron will not be pulled back to the positive plate once it moves through the hole. (OpenStax 18.53) $\mathbf{4.39 \times 10^{15}}$ **m/s², $E = 0$**



Answer to #7



Answer to #8



Electric Potential Energy

- Change in ____________ due to ____________
  - Force of gravity is ________________
  - $F_G = G\frac{m_1 m_2}{r^2}$
  - $W = mgh_0 - mgh_f = PE_0 - PE_f$
- Change in ____________ due to ____________ ____________
  - Electrical Force is ________________
  - $F_E = k\frac{q_1 q_2}{r^2}$
  - $W = PE_0 - PE_f$

Electric Potential (or Potential)

$$V = \frac{EPE}{q_0}$$

- Unit: ____________ (V = J/C)

$$V_f - V_0 = \frac{PE_f}{q_0} - \frac{PE_0}{q_0} = -\frac{W}{q_0}$$
$$\Delta V = \frac{\Delta PE}{q_0} = -\frac{W}{q_0}$$

- V and EPE can only be measured in ______________

Electric force moves a charge of 2×10^{-10}C from point A to point B and does 5×10^{-6} J of work. What is the difference in potential energies of A and B ($PE_A - PE_B$)?

What is the potential difference between A and B ($V_A - V_B$)?

Electric Potential Difference and Charge Sign

- Positive Charge
  - Moves from ____________ electrical ____________ toward ____________ electrical potential
- Negative Charge
  - Moves from ____________ to ____________ electrical potentials

Points A, B, and C are evenly spaced on a line. A positive test charge is released from A and accelerates towards B, from B it decelerates, but doesn't stop at C. What happens when a negative charge is released at B?

Batteries

- Even though it is the ____________ electrons that actually ____________, tradition says that we talk about ____________ ____________ charges
- Positive charge ____________ by ____________ terminal
- Moves through light bulb and ____________ ____________ to heat
- By the time the ____________ charge reaches the ____________ terminal, it has no ____________ energy left

Volts and Energy

$$V = \frac{EPE}{q_0}$$

$$EPE = q_0 V$$

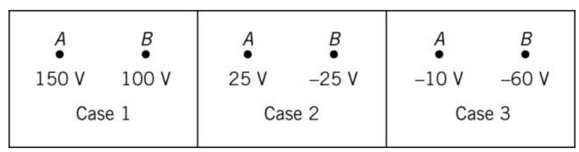
- Use this when solving ____________________ of energy problems
- Unit for _____________ energy is _____________ _____________ (eV)

$$eV = (1.60 \times 10^{-19}\ C)(1\ V) = 1.6 \times 10^{-19}\ J$$

When lightning strikes, the potential difference can be ten million volts between the cloud and ground. If an electron is at rest and then is accelerated from the ground to the cloud, how fast will it be moving when it hits the cloud 0.5 km away (ignore relativity effects)?

Homework

1. Voltage is the common word for potential difference. Which term is more descriptive, voltage or potential difference?
2. If the voltage between two points is zero, can a test charge be moved between them with zero net work being done? Can this necessarily be done without exerting a force? Explain.
3. What is the relationship between voltage and energy? More precisely, what is the relationship between potential difference and electric potential energy?
4. Voltages are always measured between two points. Why?
5. How are units of volts and electron volts related? How do they differ?
6. The drawing shows three possibilities for the potentials at two points, *A* and *B*. In each case, the same positive charge is moved from *A* to *B*. In which case, if any, is the most work done on the positive charge by the electric force? Account for your answer.



7. Find the ratio of speeds of an electron and a negative hydrogen ion (one having an extra electron) accelerated through the same voltage, assuming non-relativistic final speeds. Take the mass of the hydrogen ion to be 1.67×10^{-27} kg. (OpenStax 19.1) **42.8**
8. An evacuated tube uses an accelerating voltage of 40 kV to accelerate electrons to hit a copper plate and produce x-rays. Non-relativistically, what would be the maximum speed of these electrons? (OpenStax 19.2) $\mathbf{1.17 \times 10^8\ m/s}$
9. A bare helium nucleus has two positive charges and a mass of 6.64×10^{-27} kg. (a) Calculate its kinetic energy in joules at 2.00% of the speed of light. (b) What is this in electron volts? (c) What voltage would be needed to obtain this energy? (OpenStax 19.3) $\mathbf{1.20 \times 10^{-13}}$ **J**, $\mathbf{7.50 \times 10^5}$ **eV**, $\mathbf{3.75 \times 10^5}$ **V**
10. The temperature near the center of the Sun is thought to be 15 million degrees Celsius (1.5×10^7 °C). Through what voltage must a singly charged ion be accelerated to have the same energy as the average kinetic energy of ions at this temperature? (OpenStax 19.5) $\mathbf{1.9 \times 10^3}$ **V**
11. A lightning bolt strikes a tree, moving 20.0 C of charge through a potential difference of 1.00×10^2 MV. (a) What energy was dissipated? (b) What mass of water could be raised from 15 °C to the boiling point and then boiled by this energy? (c) Discuss the damage that could be caused to the tree by the expansion of the boiling steam. (OpenStax 19.7) $\mathbf{2.00 \times 10^9}$ **J, 766 kg, BOOM!**

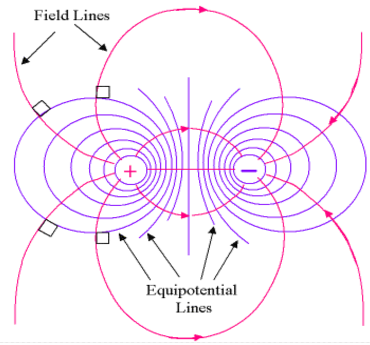
Relation between E and V

Both electric ________________ and electric ________________ can be used to describe ________________

- E
  - deals with ________________
  - ________________
- V
  - deals with ________________
  - ________________

Uniform Electric Field

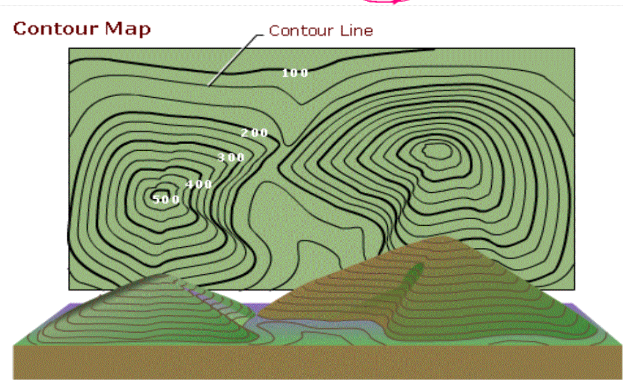
$$V_{AB} = Ed \text{ or } E = \frac{V_{AB}}{d}$$



In general

$$E = -\frac{\Delta V}{\Delta s}$$

- E is gradient (________________) of V vs. s (____________________)
- On picture, E-field lines show ________________. V lines are where V are ______________
- The closer V ________________ are, the ________________ E is.



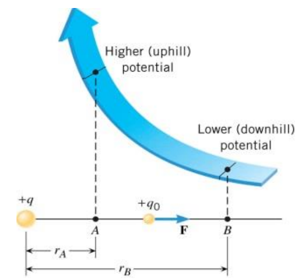
How far apart are two conducting plates that have an electric field strength of 4.50×10^3 V/m between them, if their potential difference is 15.0 kV?

A doubly charged ion is accelerated to an energy of 15.0 keV by the electric field between two parallel conducting plates separated by 3.00 mm. What is the electric field strength between the plates?

Homework

1. Discuss how potential difference and electric field strength are related. Give an example.
2. What is the strength of the electric field in a region where the electric potential is constant?
3. Will a negative charge, initially at rest, move toward higher or lower potential? Explain why.
4. Show that units of V/m and N/C for electric field strength are indeed equivalent. (OpenStax 19.13)
5. What is the strength of the electric field between two parallel conducting plates separated by 1.00 cm and having a potential difference (voltage) between them of 1.50×10^4 V? (OpenStax 19.14) $\mathbf{1.50 \times 10^6\ V/m}$
6. The electric field strength between two parallel conducting plates separated by 4.00 cm is 7.50×10^4 V/m. (a) What is the potential difference between the plates? (b) The plate with the lowest potential is taken to be at zero volts. What is the potential 1.00 cm from that plate (and 3.00 cm from the other)? (OpenStax 19.15) **3.00 kV, 750 V**
7. How far apart are two conducting plates that have an electric field strength of 4.50×10^3 V/m between them, if their potential difference is 15.0 kV? (OpenStax 19.16) **3.33 m**
8. The voltage across a membrane forming a cell wall is 80.0 mV and the membrane is 9.00 nm thick. What is the electric field strength? (The value is surprisingly large, but correct.) You may assume a uniform electric field. (OpenStax 19.18) $\mathbf{8.89 \times 10^6\ V/m}$
9. Membrane walls of living cells have surprisingly large electric fields across them due to separation of ions. What is the voltage across an 8.00 nm–thick membrane if the electric field strength across it is 5.50 MV/m? You may assume a uniform electric field. (OpenStax 19.19) **44.0 mV**
10. A doubly charged ion is accelerated to an energy of 32.0 keV by the electric field between two parallel conducting plates separated by 2.00 cm. What is the electric field strength between the plates? (OpenStax 19.22) $\mathbf{8.00 \times 10^5\ V/m}$
11. An electron is to be accelerated in a uniform electric field having a strength of 2.00×10^6 V/m . (a) What energy in keV is given to the electron if it is accelerated through 0.400 m? (b) Over what distance would it have to be accelerated to increase its energy by 50.0 GeV? (OpenStax 19.23) **800 keV, 25.0 km**

Electric Potential of a Point Charge



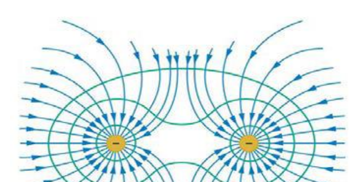
$$V = \frac{kq}{r}$$

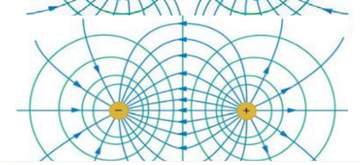
- V is ______________ the ______________ potential
- V ________ the potential difference if a test charge were __________ to a distance of r from ______________
- Two or more charges
  - Find the ______________ due to ______________ charge at that location
  - ______________ the potentials together to get the ______________ potential

Two charges are 1 m apart. The charges are +2 μC and -4 μC. What is the potential 1/3 of the way between them?

How much work is done ($-W = PE_f - PE_0$) to bring two electrons to a distance of 5.3×10^{-11} m to the nucleus of a Helium atom ($q = 3.2 \times 10^{-19}\ C$)?

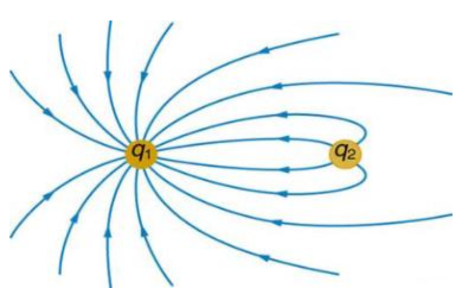
Equipotential Lines

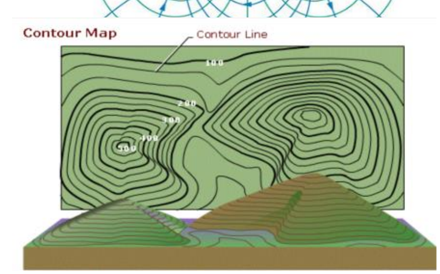




- Lines where the electric ______________ is the ______________
- Perpendicular to ______________
- No ____________ is required to move charge along ______________ line since $q\Delta V = 0$

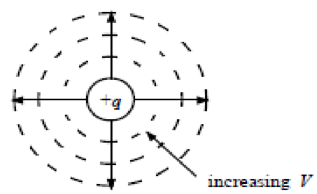
Sketch the equipotential lines in the vicinity of two opposite charges, where the negative charge is three times as great in magnitude as the positive.

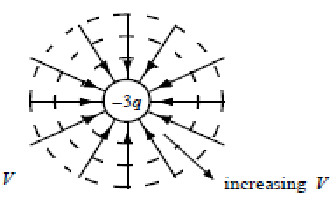




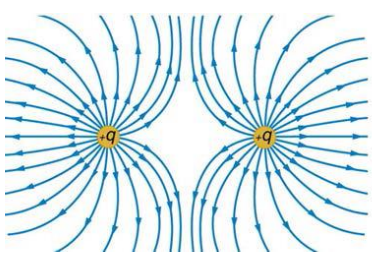
Homework

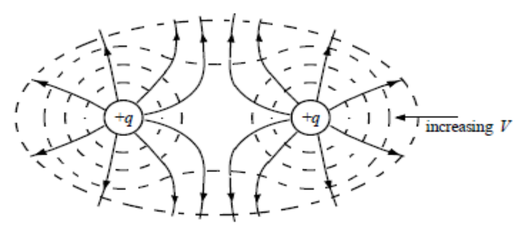
1. What is an equipotential line? What is an equipotential surface?
2. Explain in your own words why equipotential lines and surfaces must be perpendicular to electric field lines.
3. Can different equipotential lines cross? Explain.
4. Imagine that you are moving a positive test charge along the line between two identical point charges. With regard to the electric potential, is the midpoint on the line analogous to the top of a mountain or the bottom of a valley when the two point charges are (a) positive and (b) negative? Explain.
5. The potential at a point in space has a certain value, which is not zero. Is the electric potential energy the same for every charge that is placed at that point? Explain.
6. What is the potential 0.530×10^{-10} m from a proton (the average distance between the proton and electron in a hydrogen atom)? (OpenStax 19.25) **27.2 V**
7. (a) A sphere has a surface uniformly charged with 1.00 C. At what distance from its center is the potential 5.00 MV? (b) What does your answer imply about the practical aspect of isolating such a large charge? (OpenStax 19.26) **1.80 km**
8. How far from a 1.00 μC point charge will the potential be 100 V? At what distance will it be 2.00×10^{2} V? (OpenStax 19.27) **90.0 m, 45.0 m**
9. What are the sign and magnitude of a point charge that produces a potential of –2.00 V at a distance of 1.00 mm? (OpenStax 19.28) $\mathbf{-2.22 \times 10^{-13}}$ **C**
10. In nuclear fission, a nucleus splits roughly in half. (a) What is the potential 2.00×10^{-14} m from a fragment that has 46 protons in it? (b) What is the potential energy in MeV of a similarly charged fragment at this distance? (OpenStax 19.30) $\mathbf{3.31 \times 10^{6}}$ **V, 152 MeV**
11. (a) What is the potential between two points situated 10 cm and 20 cm from a 3.0 μC point charge? (b) To what location should the point at 20 cm be moved to increase this potential difference by a factor of two? (OpenStax 19.34) $\mathbf{135 \times 10^{3}}$ **V, ∞**
12. (a) Sketch the equipotential lines near a point charge $+q$. Indicate the direction of increasing potential. (b) Do the same for a point charge $-3q$. (OpenStax 19.36)



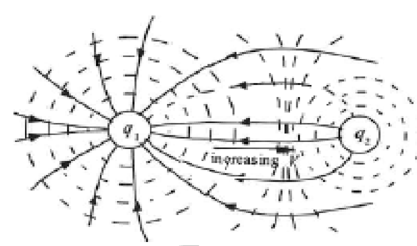


13. Sketch the equipotential lines for the two equal positive charges shown in the figure. Indicate the direction of increasing potential. (OpenStax 19.37)

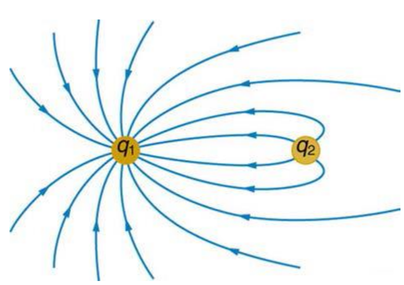


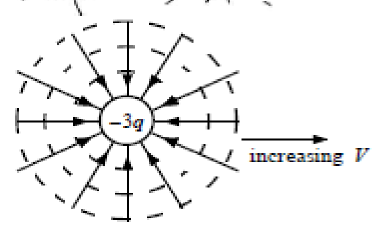


14. The figure below shows the electric field lines near two charges q_1 and q_2, the first having a magnitude four times that of the second. Sketch the equipotential lines for these two charges, and indicate the direction of increasing potential. (OpenStax 19.38)



15. Sketch the equipotential lines a long distance from the charges shown in the figure below. Indicate the direction of increasing potential. (OpenStax 19.39)





Physics

Unit 8: Electric Forces and Electric Fields

1. *What is the charge of an electron?*
2. *What is the value of k?*
3. *What are some combinations of charges that attract? Repel?*
4. *Know the steps to charge by contact and by induction.*
5. *Definitions: electric potential difference, electric potential energy, equipotential lines, electric field, electric field lines, conductors, insulators*
6. *Is electric force conservative?*
7. *A piece of wire has a charge of* -3.2×10^{-5} *C. How many extra electrons does it have?*
8. *At what separation will two charges, each of magnitude 10.0 μC, exert a force of 5 N on each other?*
9. *A -10.0-μC charge is located 0.50 m to the right of a +15.0-μC charge. What is the magnitude and direction of the electrostatic force on the positive charge?*
10. *Know about the electric field in a parallel plate capacitor.*
11. *How is the spacing of the electric field lines related to the strength?*
12. *How is the number of electric field line related to the size of the charge?*
13. *Where are the excess charges on a conductor located?*
14. *What is the magnitude and direction of the electric force on a +5 μC charge at a point where the electric field is 5000 N/C and is directed on the –x axis?*
15. *The electric potential at a certain point in space is 6 V. What is the electric potential energy of a -4 C charge placed at that point in space?*
16. *If a 2-C charge is located at the origin and a -3-C charge is located at x = 2 m, where is the electric potential zero?*
17. *If the work required to move a -0.25 C charge from point A to point B is +100 J, what is the potential difference between the two points? What is the difference in potential energies of A and B?*
18. *Given a picture of equipotential lines, be able to find area of greatest electric potential energy and electric field strength.*

1. $-1.60 \times 10^{-19}\ C$
2. $8.99 \times 10^{9}\ \frac{Nm^2}{C^2}$
3. *Attract: +,-; +,0; -,0; Repel: +, +; -, -*
4. *See textbook or notes*
7. $\frac{-3.2 \times 10^{-5}\ C}{-1.60 \times 10^{-19}\ C} = \mathbf{2.0 \times 10^{14}}\ \boldsymbol{electrons}$
8. $F = k\frac{|q_1 q_2|}{r^2}$

   $$5\ N = \left(8.99 \times 10^{9}\frac{Nm^2}{C^2}\right)\frac{|(10 \times 10^{-6}\ C)(10 \times 10^{-6}\ C)|}{r^2}$$

   $$r^2 = \left(8.99 \times 10^{9}\frac{Nm^2}{C^2}\right)\frac{|(10 \times 10^{-6}\ C)(10 \times 10^{-6}\ C)|}{5\ N}$$

   $r^2 = 0.1798\ m^2$

   $\boldsymbol{r = 0.424\ m}$
9. $F = k\frac{|q_1 q_2|}{r^2}$

   $$F = \left(8.99 \times 10^{9}\frac{Nm^2}{C^2}\right)\frac{|(-10 \times 10^{-6}\ C)(15 \times 10^{-6}\ C)|}{(0.5\ m)^2}$$

   $\boldsymbol{F = 5.39\ N\ to\ the\ right}$
10. *Constant, etc.*
11. *Wider space, less field*
12. *More lines, more charge*
13. *On surface*
14. $E = \frac{F}{q}$

    $$-5000\frac{N}{C} = \frac{F}{5 \times 10^{-6}\ C}$$

    $F = -0.025\ N$

    0.025 *N* in the -*x* direction
15. $V = \frac{EPE}{q_0}$

    $$6\ V = \frac{EPE}{-4\ C}$$

    $\boldsymbol{EPE = -24\ J}$
16. $V = \frac{kQ}{r}$

    $$\frac{k(2\ C)}{x} + \frac{k(-3\ C)}{2-x} = 0$$

    $$\frac{(2-x)k(2\ C)}{x(2-x)} + \frac{xk(-3\ C)}{x(2-x)} = 0$$

    $(2-x)(2\ C) + x(-3\ C) = 0$

    $4\ C - (2\ C)x - (3\ C)x = 0$

    $4\ C = (5\ C)x$

    $\boldsymbol{x = 0.8\ m}$
17. $V_B - V_A = \frac{EPE_B}{q_0} - \frac{EPE_A}{q_0} = \frac{-W_{AB}}{q_0}$

    $V_B - V_A = \frac{-W_{AB}}{q_0}$

    $V_B - V_A = \frac{-100\ J}{-0.25\ C} = \mathbf{400}\ \boldsymbol{V}$

    $W_{AB} = -W_{BA} = \mathbf{-100}\ \boldsymbol{J}$
18. *EPE: electron has highest EPE at lowest V and proton has highest EPE at highest V*

    E-field: highest at place where equipotential lines are closest together