Mr. Wright's Math Extravaganza

Physical Sciences
(Chemistry, Physics, Physical Science)
Electromagnetism
Units 07 Static Electricity, 08 Circuits, 09 Magnetism

Average Level for All Three Units

Level 2.0: 70% on test, Level 3.0: 80% on test, Level 4.0: level 3.0 and success on electric motor lab

Score	I Can Statements
4.0	**09 Magnetism** ☐ I can build a device that relies on electric currents producing a magnetic field or changes to a magnetic field producing electric currents to function.
3.5	In addition to score 3.0 performance, partial success at score 4.0 content.
3.0	**07 Static Electricity/09 Magnetism** ☐ I can identify similarities and differences between electrical and magnetic fields. **09 Magnetism** ☐ I can draw conclusions about the ability of electric currents to produce magnetic fields. ☐ I can draw conclusions about the ability of magnetic fields to produce electric currents.
2.5	No major errors or omissions regarding score 2.0 content, and partial success at score 3.0 content.
2.0	**07 Static Electricity** ☐ I can diagram electric fields around various charged objects by drawing appropriate field lines. ☐ I can explain how electric monopoles and dipoles create different electrical fields. **08 Circuits/09 Magnetism** ☐ I can explain the effects of creating a series of loops in a wire carrying electric current. **09 Magnetism** ☐ I can diagram magnetic fields around various charged objects by drawing appropriate field lines. ☐ I can explain how the behavior of north and south poles affects the magnetic field they create. ☐ I can explain the effects of wrapping wire carrying electric current around a core. ☐ I can explain how an electromagnet differs from a permanent magnet. ☐ I can diagram a magnetic field produced by an electric current using the right-hand rule. ☐ I can explain how multiple magnetic fields can be added together to amplify the power of a magnetic field. ☐ I can relate the ability of electric currents to create magnetic fields to the ability of changes in magnetic fields to create electric currents. ☐ I can explain the effects of moving a bar magnet through a coil of copper wire. ☐ I can explain that currents produced by changes in magnetic fields represent systems wanting to avoid change. ☐ I can use the right-hand rule to determine the direction of a current. ☐ I can relate the changes in a magnetic field and the size of the magnetic field to the amount of electric current created. ☐ I can use the Faraday-Lenz law to calculate how the change in magnetic flux generates electromotive force.

1.5	Partial success at score 2.0 content, and major errors or omissions regarding score 3.0 content.
1.0	With help, partial success at score 2.0 content and score 3.0 content.
0.5	With help, partial success at score 2.0 content but not at score 3.0 content.
0.0	Even with help, no success.

Physics 07-01 Electric Charge Name: ______________________

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
  - # ____________ = # ____________

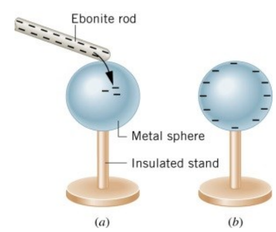
How many electrons does it take to make a charge of $-4 \times 10^{-6}\ C$? What is their mass ($m_e = 9.11 \times 10^{-31}\ kg$)?

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

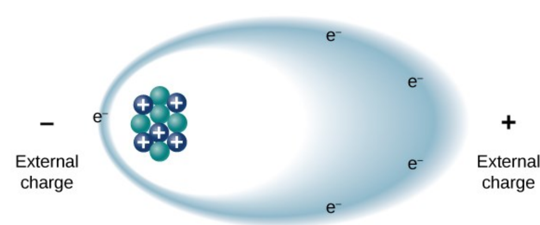
- Electricity can flow ____________ objects
- Conductors let electrons flow ____________
  - Most ____________ conductors are also ____________ conductors
  - ____________
- Insulators are very poor conductors
  - ____________ ____________ ____________



Charging by contact

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

Polarization

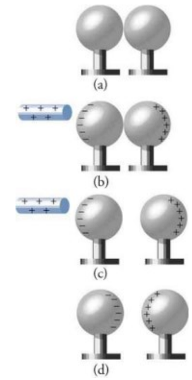


- Insulators
  - Electrons are ____________ free to move away from the atoms or molecule
  - When a ____________ is brought near, the electrons move to ____________ side of the atom/molecule so that more ____________ are on that side
  - One side is ____________, and the other side is more ____________

Physics 07-01 Electric Charge   *Name:* ________________________

Charging by Induction

- Charge without ____________
- Charged rod comes near ____________ sphere
- The like charges are ____________ to ____________ sphere
- The spheres are separated
- The _________ is removed
- Sphere is ____________



Practice Work

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. 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?
6. 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**
7. 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**
8. 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**
9. A certain lightning bolt moves 40.0 C of charge. How many fundamental units of charge $|q_e|$ is this? (OpenStax 18.4) $\mathbf{2.50 \times 10^{20}}$
10. 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) $\mathbf{1.03 \times 10^{12}}$
11. 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) $\mathbf{1.88 \times 10^{6}}$**,** $\mathbf{1.88 \times 10^{-10}}$
12. 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) $\mathbf{1.5q}$**,** $\mathbf{4q}$**,** $\mathbf{4q}$
13. Consider four identical metal spheres, A, B, C, and D. Sphere A carries a charge of 5×10^{-6} C. Sphere B carries a charge of 2×10^{-6} C. Sphere C carries a charge of -3×10^{-6} C. And, Sphere D carries a charge of -4×10^{-6} C. Spheres A and C are touched together and then separated. Spheres B and D are touched together and then separated. Sphere C is touched to sphere B and separated. Last, sphere D is touched to sphere C and separated. (a) How much charge ends up on each sphere? (b) What is the total charge on the four spheres before they were touched and (c) after they have touched? (RW) $\mathbf{1\times10^{-6}}$ **C, 0 C,** $\mathbf{-0.5\times10^{-6}}$ **C,** $\mathbf{-0.5\times10^{-6}}$ **C; 0 C; 0 C**

Physics 07-02 Coulomb's Law	*Name: ________________________*
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

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

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

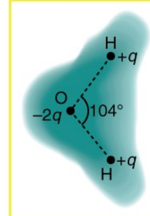
- Work in ____________ parts
  - Find ____________ of attraction by ____________ of the points
  - Find ____________ of attraction by the ____________ point
  - Add the force ____________
    - REMEMBER!!!!! You have to add the ____________ and ____________ ________________!!!!!

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?

Physics 07-02 Coulomb's Law ***Name: ________________________***

Practice Work



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) $\mathbf{1.26 \times 10^{-3} N}$
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) **0.262 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) **7.11 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) $\mathbf{3.45 \times 10^{16}}$ $\mathbf{m/s^2}$
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) $\mathbf{4.16 \times 10^{42}}$**,** $\mathbf{1.24 \times 10^{36}}$

Physics 07-03 Electric Field Name: ________________________

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.

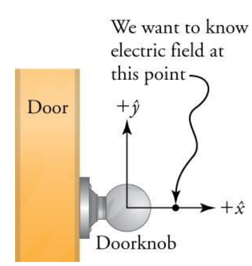
Electric Field Definition

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

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

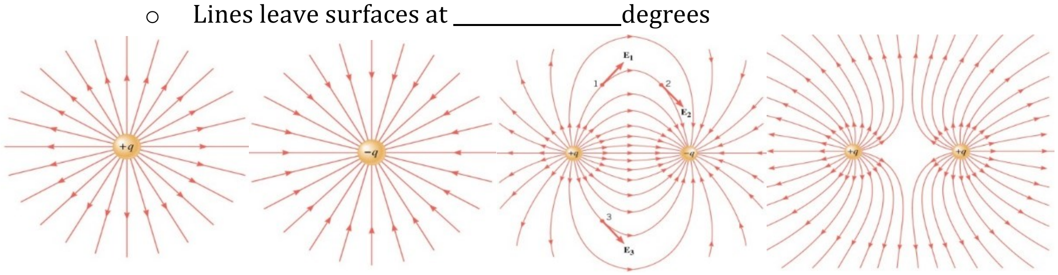
There are two point charges of $q_1 = 4\ C$ and $q_2 = 8\ C$ and they are 10 m apart. Find point where E = 0 between them.

A doorknob, which can be taken to be a spherical metal conductor, acquires a static electricity charge of $-1.5\ nC$ What is the electric field 1.0 cm in front of the doorknob? The diameter of the doorknob is 5.0 cm.



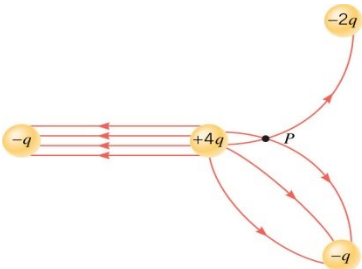
Electric Field Lines

- 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

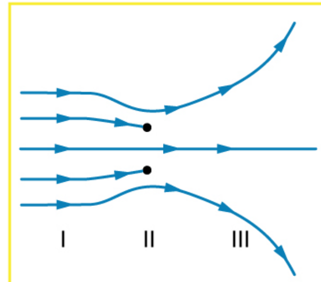


Physics 07-03 Electric Field **Name: ______________________**

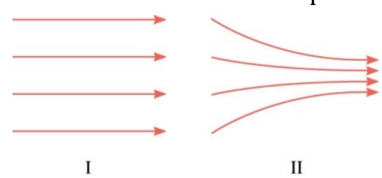
What is wrong here?



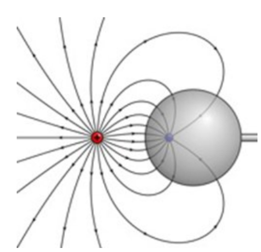
Practice Work



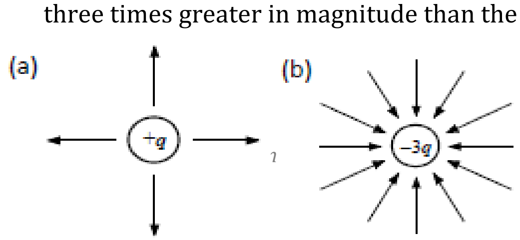
1. Why must the test charge q_0 in the definition of the electric field be vanishingly small?
2. Explain how electric monopole (single charge) and dipole (two charges) create different electric fields. Sketch examples of each.
3. The figure shows an electric field extending over three regions, labeled 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?
4. 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?

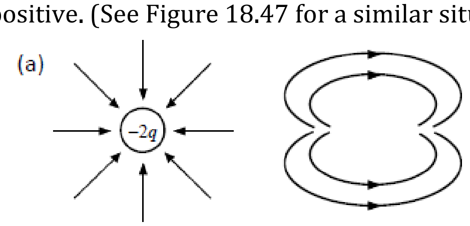


5. Drawings I and II show two examples of electric field lines. Decide which of the following statements are true and which are false, defending your choice in each case. (a) In both I and II the electric field is the same everywhere. (b) As you move from left to right in each case, the electric field 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.
6. 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**
7. 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**
8. 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) $\mathbf{1.12 \times 10^{7}}$ **N/C**
9. (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) $\mathbf{6.95 \times 10^{-8}}$ **C, 6.25 N/C**
10. (a) Find the direction and magnitude of an electric field that exerts a 4.80×10^{-17} N west 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**
11. (a) Sketch the electric field lines near point charge $+q$. (b) Do the same for point charge $-3.00q$. (OpenStax 18.33) **below**
12. 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**

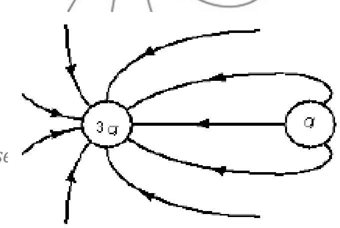


13. The figure shows the electric field lines near two charges q_1 and q_2. (a) What is the ratio of their magnitudes? (b) Sketch the electric field lines a long distance from the charges shown in the figure. (OpenStax 18.35) **−1.9:1, like a point charge**
14. Sketch the electric field lines in the 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).





To be use



Physics 07-04 Electric Potential   *Name: ________________________*

Electric Potential Energy

- Change in ______________ due to ______________
  - $F_G = G\frac{m_1 m_2}{r^2}$
  - $W = mgh_0 - mgh_f = PE_0 - PE_f$
- Change in __________ due to ______________ ________
  - $F_E = k\frac{q_1 q_2}{r^2}$
  - $W = PE_0 - PE_f$
- PE can only be differences because there is no absolute _____________ position
- For point charges: $\boldsymbol{PE = \frac{kqq_0}{r}}$

Electric Potential (or Potential)

$$\boldsymbol{V = \frac{\Delta PE}{q_0}}$$

- For point charges: $\boldsymbol{V = \frac{kq}{r}}$

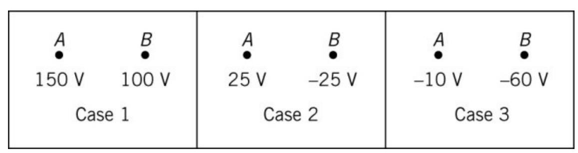
Potential Energy	Electrical Potential
Symbol: _________ $PE = q_0 V$ Unit: _________	Symbol: _________ $V = \frac{\Delta PE}{q_0}$ Unit: _________

- To add potentials from several point charges, ____________ the potentials at that point

Two point-charges lie on the *x*-axis with $q_1 = -2\ \mu C$ at 1 cm and $q_2 = 3\ \mu C$ at 9 cm. Where is the electric potential zero between them?

Practice Work

12. Voltage is the common word for potential difference. Which term is more descriptive, voltage or potential difference?
13. What is the relationship between voltage and energy? More precisely, what is the relationship between potential difference and electric potential energy?
14. Voltages are always measured between two points. Why?
15. 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.



16. 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.
17. 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**
18. 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) **89.9 m, 45.0 m**
19. 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) $\boldsymbol{-2.22 \times 10^{-13}}$ **C**
20. 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) $\boldsymbol{3.31 \times 10^6}$ **V, 152 MeV**

21. 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**

22. 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) $\mathbf{1.17 \times 10^{8}\ m/s}$

23. 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)?

[illegible]

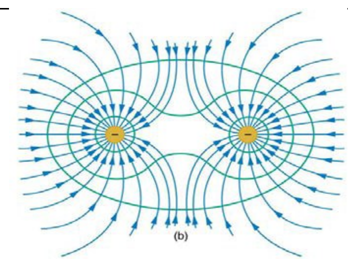
Physics 07-05 Potential and E-Field | *Name: ________________________*

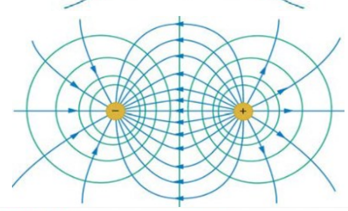
Electric Potential and E-field

- $E = \frac{\Delta V}{x_f - x_0}$
- E-field units: ____________ or ____________
- It is easy to measure ____________. To find E-field, divide ΔV and the ________________ between two points

What is the voltage difference between the positions, x = 11 m and x = 5.0 m in an electric field of 2.0 N/C?

X-ray tubes that generate X-rays contain an electron source separated by about 10 cm from a metallic target. The electrons are accelerated from the source to the target by a uniform electric field with a magnitude of about 100 kN/C. When the electrons hit the target, X-rays are produced. (a) What is the potential difference between the electron source and the metallic target? (b) What is the kinetic energy of the electrons when they reach the target, assuming that the electrons start at rest?

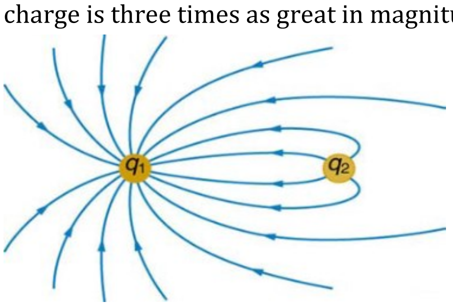




Equipotential Lines

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

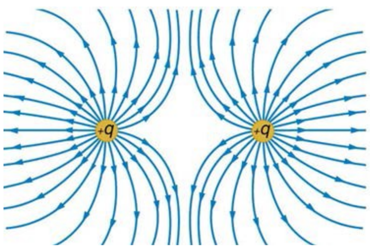
Sketch the equipotential lines in the vicinity of two opposite charges, where the negative charge is three times as great in magnitude as the positive.



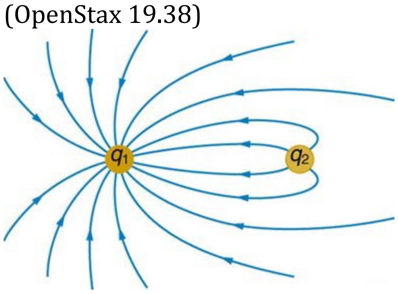
Practice Work

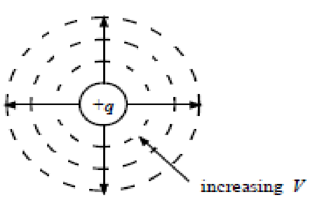
1. What is an equipotential line? What is an equipotential surface?
2. Explain in your own words why equipotential lines and surfaces must be perpendicular to electric field lines.
3. Can different equipotential lines cross? Explain.
4. What is the strength of the electric field between two parallel conducting plates separated by 1.00 cm and having a potential difference (voltage) between them of 1.50×10^4 V? (OpenStax 19.14) $\mathbf{1.50 \times 10^6\ V/m}$
5. 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**

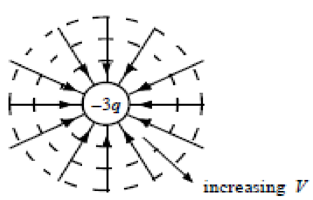
6. How far apart are two conducting plates that have an electric field strength of 4.50×10^3 V/m between them, if their potential difference is 15.0 kV? (OpenStax 19.16) **3.33 m**
7. The voltage across a membrane forming a cell wall is 80.0 mV and the membrane is 9.00 nm thick. What is the electric field strength? (The value is surprisingly large, but correct.) You may assume a uniform electric field. (OpenStax 19.18) $\mathbf{8.89 \times 10^6\ V/m}$
8. 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**
9. (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)
10. Sketch the equipotential lines for the two equal positive charges shown in the figure. Indicate the direction of increasing potential. (OpenStax 19.37)

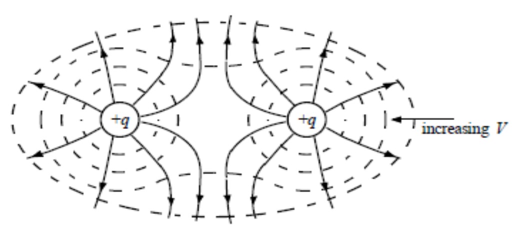


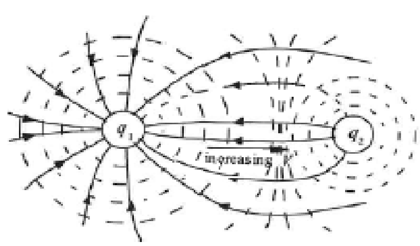
11. The figure below shows the electric field lines near two charges q_1 and q_2, the first having a magnitude four times that of the second. Sketch the equipotential lines for these two charges, and indicate the direction of increasing potential. (OpenStax 19.38)











Physics Unit 7*:* Static Electricity *Review*

1. Know about electric potential difference, electric potential energy, equipotential lines, electric field, electric field lines, conductors, insulators
2. What is the charge of an electron?
3. What is the value of k?
4. What are some combinations of charges that attract? Repel?
5. Know the steps to charge by contact and by induction.
6. Be able to draw electric field lines and equipotential lines.
7. Be able to read electric field map and equipotential lines to determine where the E-field is greatest and potential is greatest
8. A conducting sphere has a net charge of -5×10^{-18} C. What is the approximate number of excess electrons on the sphere?
9. At what separation will two charges, each of magnitude 5 mC, exert a force of 10 N on each other?
10. A –10-μC charge is located 0.75 m to the right of a +15-μC charge. What is the magnitude and direction of the electrostatic force on the positive charge?
11. What is the magnitude and direction of the electric force on a −10 μC charge at a point where the electric field is 2100 N/C and is directed along the $+x$ axis.
12. If the work required to move a +3 μC charge from point **A** to point **B** is +500 J, what is the potential difference between the two points?
13. What is the electric potential energy of a 2 μC charge located at a point in space 3 cm away from a charge where the electric potential is 75 V?
14. How far from a 0.3 C charge is the electric potential 5000 V?
15. What is the electric field that accelerates proton from a location with 15 V to a location with 25 V over a distance of 5 cm?
16. Draw an electric field diagram around a $+q$ charge.
17. Draw the electric field around the two charges.

Physics Unit 7: Static Electricity *Review*

Answers

2. **-1.6×10^{-19} C**

3. **$k = 8.99\times10^{9}$ Nm²/C²**

4. Attract: +,−; +, 0 from polarization; −, 0 from polarization
   Repel: +,+; −,−

5. Contact: Touch a conductor with a charged object. Charges flow until the charges are the same on each object.
   Induction: Set up two conductors touching each other. Bring a charged object near one conductor on the side opposite the other conductor. The charges will repel to the other conductor. Separate the conductors. Remove the charged object.

6. See notes

7. E-field is greatest where the lines are the closest. Potential is greatest near a positive charge.

8. $\frac{-5\times10^{-18}\ C}{-1.6\times10^{-19}\ C} = 31.25$; **31 electrons** (no partial electrons exist. The decimal is due to precision of the measurements.)

9. $F = \frac{kq_1q_2}{r^2}$
   $10\ N = \frac{\left(8.99\times10^{9}\frac{Nm^2}{C^2}\right)(5\times10^{-3}\ C)(5\times10^{-3}\ C)}{r^2}$
   $10\ N = \frac{224750\ Nm^2}{r^2}$
   $(10\ N)r^2 = 224750\ Nm^2$
   $r^2 = 22475\ m^2$
   $\boldsymbol{r = 150\ m}$

10. $F = \frac{kq_1q_2}{r^2}$
    $F = \frac{\left(8.99\times10^{9}\frac{Nm^2}{C^2}\right)(-10\times10^{-6}\ C)(15\times10^{-6}\ C)}{(0.75\ m)^2}$
    $F = -2.40\ N$
    ***F* = 2.40 N to the right** (because opposite charges attract)

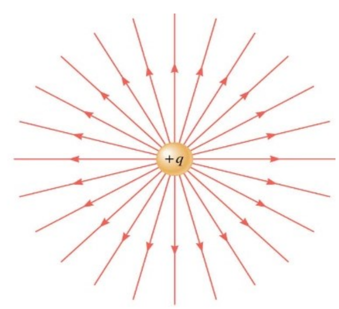
11. $E = \frac{F}{q_0}$
    $2100\frac{N}{C} = \frac{F}{-10\times10^{-6}\ C}$
    $-0.021\ N = F$
    ***F* = 0.021 N along −x-axis** (because the negative charge goes the opposite direction of *E*.)

12. $V = \frac{\Delta PE}{q_0}$
    $V = \frac{500\ J}{3\times10^{-6}\ C}$
    $\boldsymbol{V = 1.67\times10^{8}\ V}$

13. $V = \frac{\Delta PE}{q_0}$
    $75\ V = \frac{\Delta PE}{2\times10^{-6}\ C}$
    $\boldsymbol{1.5\times10^{-4}\ J = \Delta PE}$

14. $V = \frac{kq}{r}$
    $5000\ V = \frac{\left(8.99\times10^{9}\frac{Nm^2}{C^2}\right)(0.3\ C)}{r}$
    $5000\ V = \frac{2.697\times10^{9}\frac{Nm^2}{C}}{r}$
    $(5000\ V)r = 2.697\times10^{9}\frac{Nm^2}{C}$
    $\boldsymbol{r = 5.39\times10^{5}\ m}$

15. $E = \frac{\Delta V}{x_f - x_0}$
    $E = \frac{25\ V - 15\ V}{0.05\ m}$
    $\boldsymbol{E = 200\frac{V}{m}}$

16.


17.