Electrostatics and Electric Potential - Outline

1. Understand the basic properties of electric charge, including conservation of charge and that charges are quantized.
2. Differentiate between conductors and insulators.
3. Distinguish between charging by contact, charging by induction, and charging by polarization.
4. Calculate electric force using Coulomb's law.
5. Compare electric force with gravitational force.
6. Apply the superposition principle to find the resultant force on a charge and to find the position at which the net force on a charge is zero
7. Calculate electric field strength.
8. Draw and interpret electric field lines.
9. Identify the four properties associated with a conductor in electrostatic equilibrium
10. Distinguish between electrical potential energy, electric potential, and potential difference.
11. Solve problems involving electrical energy and potential difference.
12. Describe the energy conversions that occur in a battery.
13. Relate capacitance to the storage of electrical potential energy in the form of separated charges.
14. Calculate the capacitance of various devices.
15. Calculate the energy stored in a capacitor.

Notes

- <u>Properties of Electric Charge</u>
  - ✓ Like and Unlike charges:
  - ✓ Conservation of Charge:
  - ✓ Electric charge is Quantized:
- <u>Transfer of Electric Charge</u>
  - ✓ Electrical Conductors:
  - ✓ Electrical Insulators:
  - ✓ Conduction:

- ✓ Induction:

- ✓ Polarization:

- <u>Coulomb's Law</u>

  - ✓ Example:

<u>Compare and Contrast Electrical Force and Gravitational Force</u>

- ✓ Compare:

- ✓ Contrast:

- <u>Electric Field</u>

  - ✓ Electric Field Strength of a Point Charge:

- <u>Electric Field Lines</u>

    - ✓ Rules

- <u>Conductors in Electrostatic Equilibrium</u>

    - ✓ Rules:

- <u>Electrical Potential Energy</u>

- <u>Electric Potential</u>

- <u>Potential Difference</u>

    - ✓ Potential Difference in a Uniform Electric Field

    - ✓ Potential Difference between a Point at Infinity and a Point near a Point Charge:

- <u>Capacitance</u>

  - ✓ Charging and Discharging:

  - ✓ Common Devices that use Capacitors

  - ✓ Capacitance for a Parallel-Plate Capacitor in a Vacuum:

- <u>Electrical Potential Energy Stored in a Capacitor</u>

• **Sample/Practice Problems**

1. **Electrostatics and transfer of charge**

Electrostatics

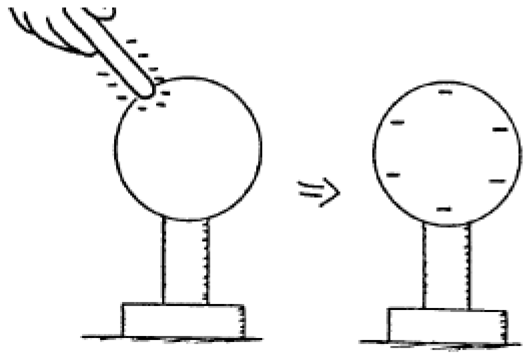
1. The outer electrons in metals are not tightly bound to the atomic nuclei. They are free to roam in the material. Such materials are good

   (conductors) (insulators)

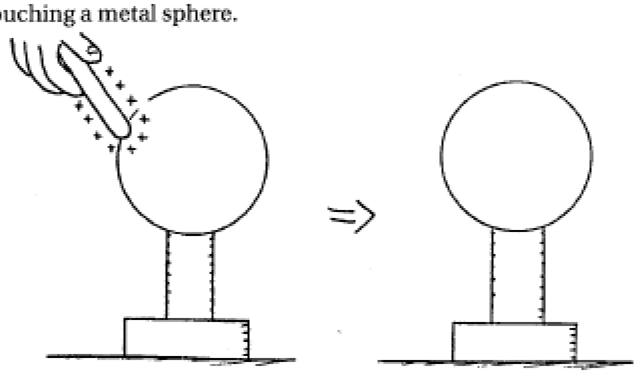
   Electrons in other materials are tightly bound to the atomic nuclei, and are not free to roam in the material. These materials are good

   (conductors) (insulators)

2. A rubber rod that has been rubbed with fur is negatively charged because rubber holds electrons better than fur does. When the rod touches a metal sphere, some of the charge from the rod spreads onto the metal sphere because like charges repel one another. When the rod is removed the charge spreads evenly over the metal sphere and remains there because the insulating stand prevents its flow to the ground. The negatively charged rod has given the sphere a negative charge. This is c*harging by contact*, and is shown to the right.



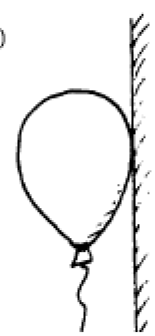
   Label the right-hand sphere below with the appropriate charges below for a positively-charged rod touching a metal sphere.



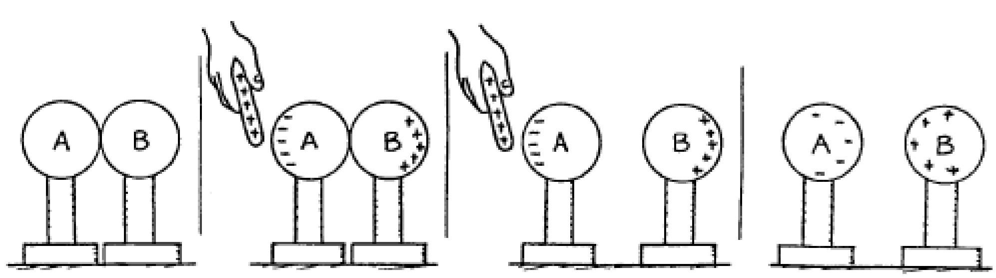
3. In the examples above, electric charge is

   (created from nothing)   (simply transferred from one body to another)

4. A positively-charged balloon will stick to a wooden wall. It does this by polarizing molecules in the wooden wall to create an oppositely-charged surface. Draw the appropriate charges on both the balloon and in the wall. Your completed diagram should be similar to Figure 32.13 in your textbook.

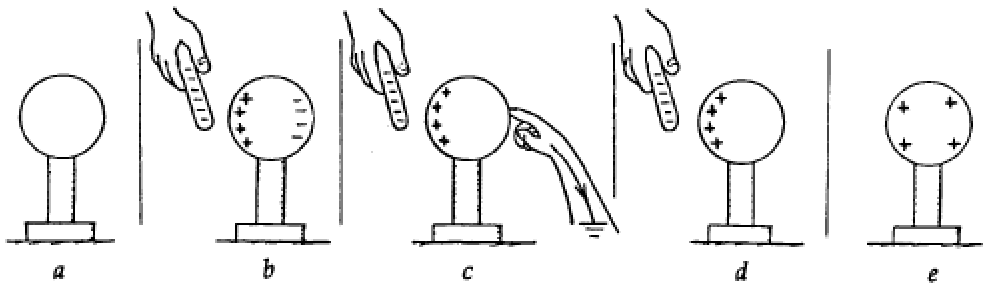


5. Consider the diagrams below. (a) A pair of insulated metal spheres, A and B, touch each other, so in effect they form a single uncharged conductor. (b) A positively charged rod is brought near A, but not touching, and electrons in the metal sphere are attracted toward the rod. Charges in the spheres have redistributed, and the negative charge is labeled. Draw the appropriate + signs that are repelled to the far side of B. (c) Draw the signs of charge in (c), when the spheres are separated while the rod is still present, and in (d) after the rod has been removed. Your completed work should be similar to Figure 32.8 in the textbook. The spheres have been charged by *induction*.

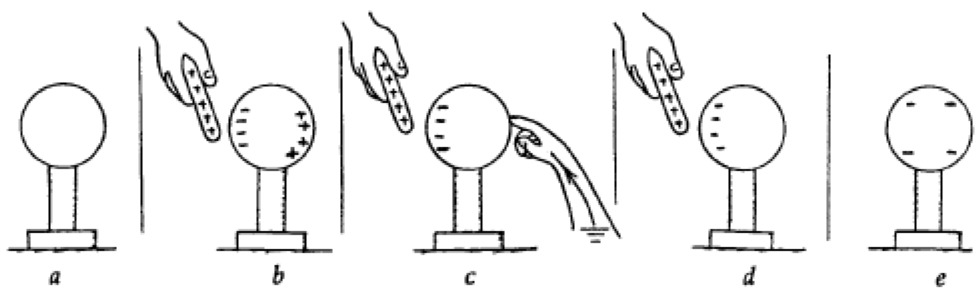


a   *b*   *c*   *d*

6. Consider below a single metal insulated sphere, (a) initially uncharged. When a negatively charged rod is nearby, (b), charges in the metal are separated. Electrons are repelled to the far side. When the sphere is touched with your finger, (c), electrons flow out to the sphere to the earth through the hand. The sphere is "grounded." Note the positive charge left (d) while the rod is still present and your finger removed, and (e) when the rod is removed. This is an example of *charge induction by grounding*. In this procedure the negative rod "gives" a positive charge to the sphere.



The diagrams below show a similar procedure with a positive rod. Draw the correct charges in the diagrams.



B. Coulomb's Law

1. If a neutral Lucite rod is rubbed with wool and acquires a charge of -4.0 x 10^{-6} C, what is the charge on the wool?

2. If a point charge of 0.008 C is brought to 0.5 m away from a second point charge of 0.07 C, what is the repulsive force acting on the first point charge? What is the repulsive force acting on the second charge?

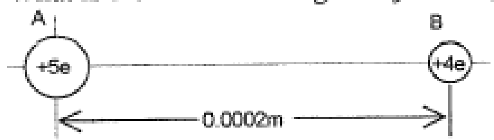
3. If a neutral object loses 1000 electrons, it will have a net charge of : (in terms of elementary charges)

4. If a neutral object loses 1000 electrons, it will have a net charge of : (in terms coulombs)

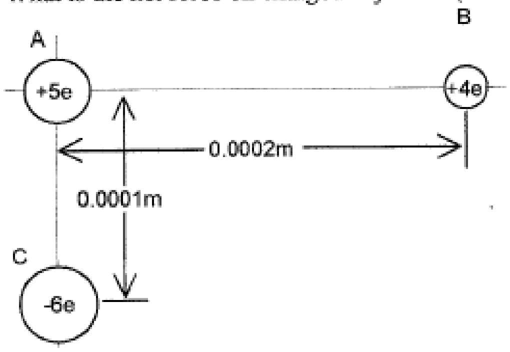
5. Two objects have equal but opposite charges on them and there is a force of attraction of 1 N when separated by a distance of 0.005 m. What is the charge on each of the objects?

6. The force between an electron and a proton is 0.01 N, what is the distance between the these two point charges

7. What is the force on charged object **A**? *(hint: charges must be in Coulombs)*



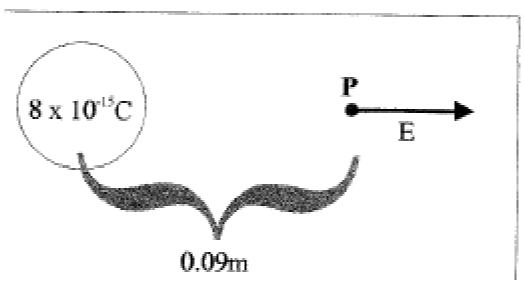
8. What is the net force on charged object A? *(hint: you've already calculated the components)*



C. Electric Fields

1. .Sketch a field map for the following situation.

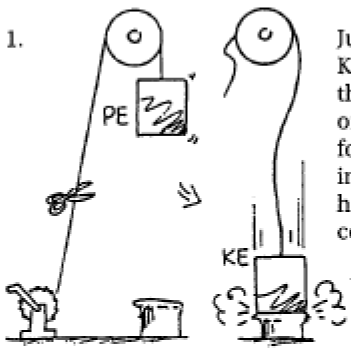
2. Find the electric field intensity (magnitude and direction)at point **P** as shown in the diagam below.



3. A test charge of -1.2×10^{-6} C experiences a force of 2 N. What is the intensity of the field at the location of the test charge?

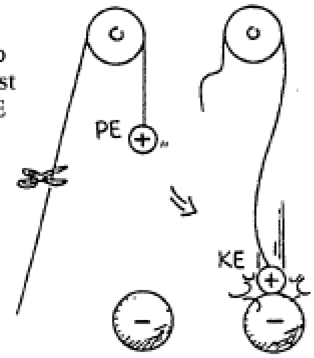
D. Electric Potential

1.

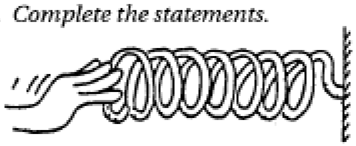


Just as PE (potential energy) transforms to KE (kinetic energy) for a mass lifted against the gravitational field (left), the electric PE of an electric charge transforms to other forms of energy when it changes location in an electric field (right). When released, how does the KE acquired by each compare to the decrease in PE?

____



2. *Complete the statements.*



A force compresses the spring. The work done in compression is the product of the average force and the distance moved. W = Fd. This work increases the PE of the spring.

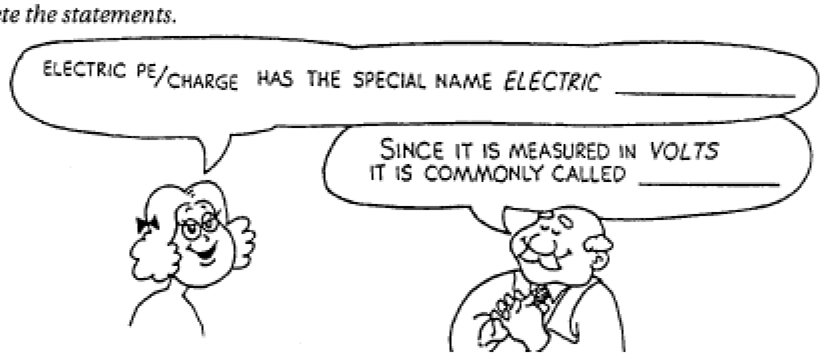
Similarly, a force pushes the charge (call it a test charge) closer to the charged sphere. The work done in moving the test charge is the product of the average ________ and the _________ moved. W = _______. This work _____________ the PE of the test charge.

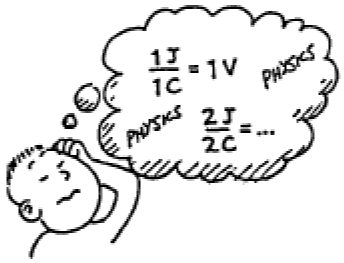
If the test charge is released, it will be repelled and fly past the starting point. Its gain in KE at this point is ____________________ to its decrease in PE.

At any point, a greater quantity of test charge means a greater amount of PE, but not a greater amount of PE *per quantity* of charge. The quantities PE (measured in joules) and PE/charge (measured in volts) are different concepts.

By definition: **Electric Potential = PE/charge.** 1 volt = 1 joule/1coulomb.

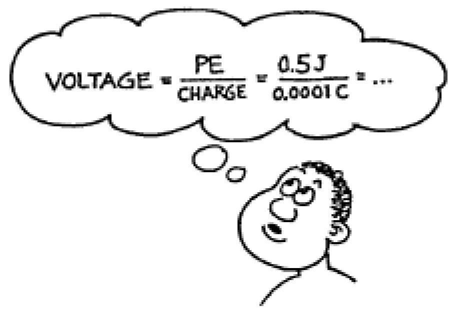
3. *Complete the statements.*





4. When a charge of 1 C has an electric PE of 1 J, it has an electric potential of 1 V. When a charge of 2 C has an electric PE of 2 J, its potential is = __________V.

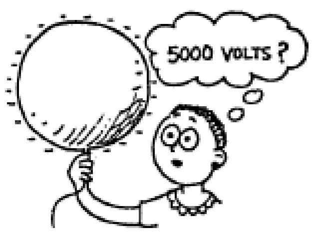
5. If a conductor connected to the terminal of a battery has a potential of 12 volts, then each coulomb of charge on the conductor has a PE of ___________ J.



6. If a charge of 1 C has a PE of 5000 J, its voltage is ______________________V.

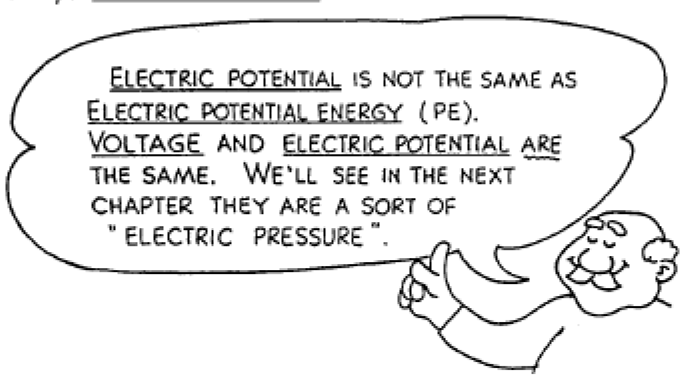
7. If a charge of 0.001 C has a PE of 5 J, its voltage is ______________________V.

8. If a charge of 0.0001 C has a PE of 0.5 J, its voltage is ______________________V.



9. If a rubber balloon is charged to 5000 V, and the quantity of charge on the balloon is 1 millionth coulomb, (0.000001 C) then the PE of this charge is only _______________ J.

10. Some people get mixed up between force and pressure. Recall that pressure is force *per area.* Similarly, some people get mixed up between electric PE and voltage. According to this chapter, voltage is electric PE *per* ___________________.



Homework Problems:

I. Coulomb's Law

1. If a neutral Lucite rod is rubbed with wool and acquires a charge of $+6.0 \times 10^{-6}$ C, what is the charge on the wool?

2. If a point charge of 2 µC is brought to 0.5 m away from a second point charge of 7 µC, what is the repulsive force acting on the first point charge? What is the repulsive force acting on the second charge? (Remember that $\mu C = 1 \times 10^{-6}$ C)

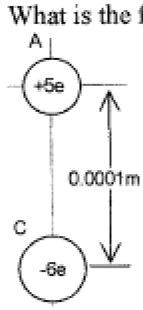
3. If a neutral object loses a million electrons, it will have a net charge of : (in terms of elementary charges)

4. If a neutral object loses million electrons, it will have a net charge of : (in terms coulombs)

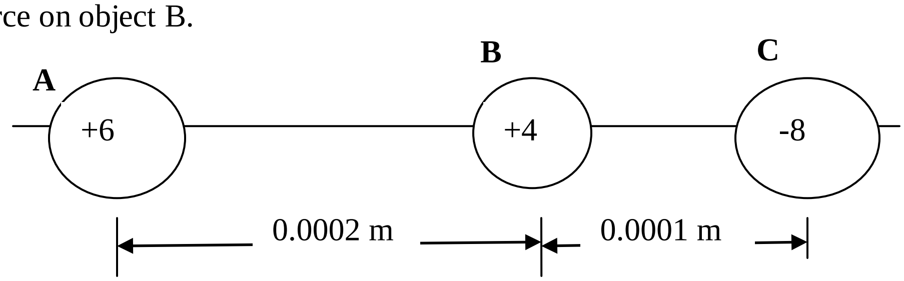
5. Two objects have equal but opposite charges on them and there is a force of attraction of 15 N when separated by a distance of 0.05 m. What is the charge on each of the objects?

6. The force between an electron and a proton is 6×10^{-40} N, what is the distance between the these two point charges

7. What is the force on charged object **A**?



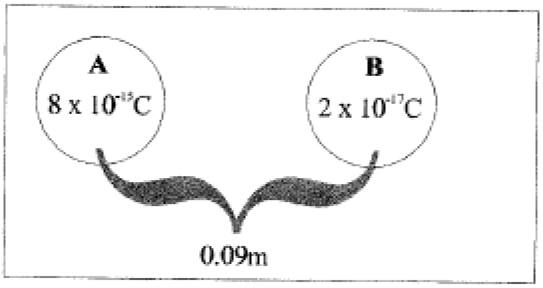
8. Three charges (in nanocoulombs (10^{-9}C)) are arranged as shown in the diagram below. Find the net force on object B.



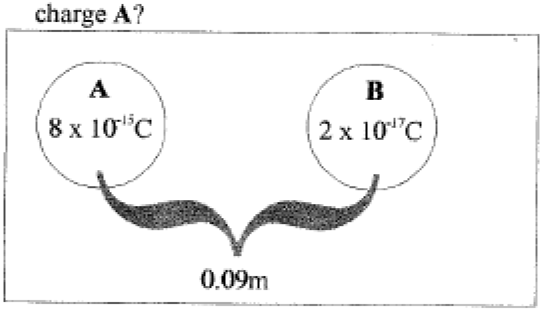
II. Electric Fields

1. A test charge of $+2.0 \times 10^{-12}$ C experiences a force of 0.006 N. What is the intensity of the field at the location of the test charge?

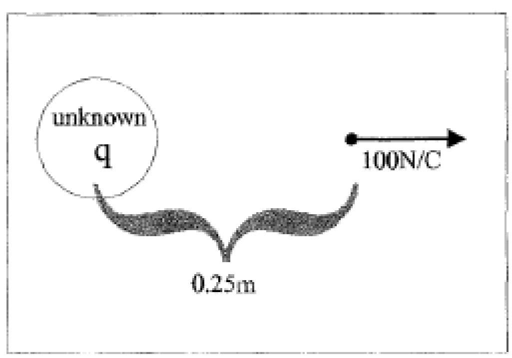
2. What is the force on charge **B**?



3. Using your answer for question 2, what is the field intensity (magnitude and direction) at point **B** as a result of charge **A**?



4. An electric field is determined to have an intensity of 100 N/C at a distance of 0.25 m from the charged object. What is the charge on the object?



5.

An object with a charge of 3.2×10^{-4}C is held in a fixed position. A test charge of -1.1×10^{-8}C is brought to 0.09m away from the object.

a) At this distance what is field intensity of the object?

b) What is the force on the test charge?