

Charge

Read from **Lesson 1** of the **Static Electricity** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/estatics/u8l1a.html>

<http://www.physicsclassroom.com/Class/estatics/u8l1b.html>

MOP Connection: Static Electricity: sublevel 1

Introduction:

It all begins with atoms. An understanding of static electricity begins with an understanding of the atom. Matter is made of atoms and if any sample of matter is charged, becomes charged or loses a charge, then the explanation of what happened demands that one understand matter at the *particle level*.

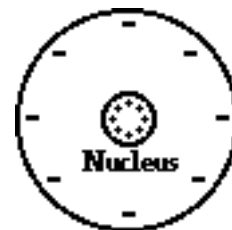
1. In the space at the right, draw a picture of your understanding of the structure of an atom. What does it look like? What is inside of it? Express what you know using a well-labeled diagram.
 2. The charged parts of the atom are the _____ and the _____. The _____ are positively charged and the _____ are negatively charged. The _____ are not charged and thus will not be of importance in this unit.
 3. An electrically neutral atom is an atom which _____.
 - a. does not have any protons or electrons
 - b. has more neutrons than the sum of all its protons and electrons
 - c. has a balance of protons and electrons (the same number of each)
 - d. has a balance of neutrons and electrons (the same number of each)
 - e. has a balance of protons, electrons and neutrons (the same number of each)
 4. An electrically charged atom (sometimes referred to as an ion) can be distinguished from an electrically neutral atom in that the charged atom (ion) _____.
 - a. does not have any neutrons
 - b. has lost one or more of its neutrons
 - c. either has a proton or an electron present somewhere within it
 - d. has a different number of neutrons than the sum of its electrons and protons
 - e. has an imbalance of protons and electrons (unequal numbers of these)

Structure of the Atom

Physics Fact:

Protons (and neutrons) are located in the *interior* of an atom - in the nucleus. They are tightly bound and unable to leave the atom except through nuclear processes. On the other hand, electrons are on the *exterior* of an atom. They are exposed to other atoms and to forces that are capable of *ejecting* them or *stripping* them of the atom.

5. The diagram at the right depicts the eight electrons and eight protons in an oxygen atom.
 - a. Explain what must happen in order for an oxygen atom to become negatively charged.
 - b. Explain what must happen in order for an oxygen atom to become positively charged.



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6. What is true of atoms in terms of being neutral, negatively charged, and positively charged is also true of objects. An object that is negatively charged must have _____ (more, less, the same number of) electrons compared to its protons. An object that is positively charged must have _____ (more, less, the same number of) electrons compared to its protons. An object that is electrically neutral must have _____ (more, less, the same number of) electrons compared to its protons.

Summarize these verbal statements by inserting >, < or = symbols into the blanks below:

Negatively Charged
of e^- _____ # of p^+

Positively Charged
of e^- _____ # of p^+

Electrically Neutral
of e^- _____ # of p^+

7. An object becomes charged due to an excess or deficiency (shortage) of electrons. Knowing the exact number of excess or deficient electrons in an object allows one to determine the object's charge. The charge of one electron is 1.6×10^{-19} C. Use this to determine the charge of the following objects.

Object	# of Excess or Deficient Electrons	Quantity and Kind of Charge (Q) on Object in Coulombs (C)
A	1.0×10^3 excess electrons	
B	1.0×10^6 deficient electrons	
C	2.0×10^9 excess electrons	
D	2.5×10^8 deficient electrons	
E	6.82×10^{12} excess electrons	

8. During a physics lab, a plastic strip was rubbed with cotton and became positively charged. The correct explanation for why the plastic strip becomes positively charged is that ...
- the plastic strip acquired extra protons from the cotton.
 - the plastic strip acquired extra protons from the charging process.
 - protons were created as the result of the charging process.
 - the plastic strip lost electrons to the cotton during the charging process.
9. Miss Chiff, the seventh-grade science teacher, greets her students in an unusual manner. She stands at the door of her classroom, scuffing her feet back and forth on the carpet. As she does so, electrons move from the carpet to her shoes to her body. Miss Chiff is now charged with a _____ (positive, negative) type of charge.
- Then, Miss Chiff reaches out and touches her students on the nose as they enter the classroom. As she does, some electrons leave Miss Chiff and move onto her students. Miss Chiff is now _____ (more, less) negatively charged than before the contact with the student. And the student is now charged with a _____ (positive, negative) type of charge.
10. In a lab report during the Static Electricity unit, Aaron Agin suggests that a sample of wool became positively charged by gaining protons from the rubber balloon that it rubbed. Explain what is wrong with Aaron's statement.

Charge Interactions

Read from **Lesson 1** of the **Static Electricity** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/estatics/u8l1c.html>

MOP Connection: Static Electricity: sublevel 2

1. **Review:** Fill in the following blanks with the words **electrons** or **protons**.

_____ are negatively charged and _____ are positively charged. As an object begins to gain or lose electrons from its atoms, it becomes positively or negatively charged. A negatively charged object has more _____ than _____. A positively charged object has more _____ than _____.

2. Charged objects interact with one another. One can observe the interactions and infer information about the type of charge present on an object. Complete the following statements to illustrate your understanding of the three types of charge interactions:

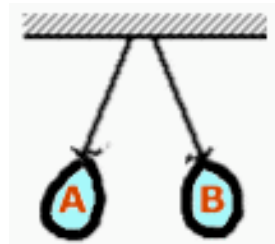
- a. Oppositely-charged objects _____.
- b. Like-charged objects _____.
- c. A charged object and a neutral object will _____.

3. Your physics teacher has prepared the room for the class's entry by suspending several inflated balloons from the ceiling. Upon entering the physics room, you observe two balloons being drawn towards each other as shown at the right. The attraction of these balloons for one another provides evidence that _____.



- a. both balloons are charged with the same type of charge
- b. both balloons are charged with the opposite type of charge
- c. both balloons are charged - either with the same type or opposite type of charge
- d. only one of the balloons is charged; the other is neutral
- e. at least one of the balloons is charged; the other is either charged or neutral

4. As you look around the room, you observe two other balloons being pushed away from each other as shown at the right. The repulsion of these balloons from one another provides evidence that _____.



- a. both balloons are charged with the same type of charge
- b. both balloons are charged with the opposite type of charge
- c. both balloons are charged - either with the same type or opposite type of charge
- d. only one of the balloons is charged; the other is neutral
- e. at least one of the balloons is charged; the other is either charged or neutral

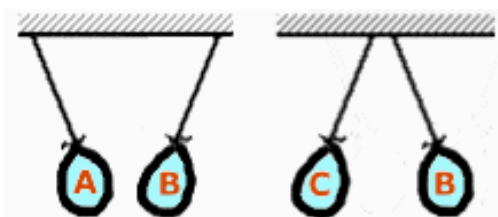
5. In one part of the room, there are two balloons - one hanging straight down and the other being attracted to it. This is evidence that _____.



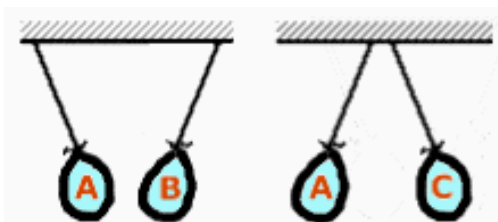
- a. balloon A is charged and balloon B is neutral
- b. balloon B is charged and balloon A is neutral
- c. balloon A is neutral and balloon B is negative
- d. balloon A is neutral and balloon B is positive
- e. ... nonsense! This would never happen if the balloons are identical and simply suspended by strings. They will attract each other and both be deflected from a vertical orientation.

Static Electricity

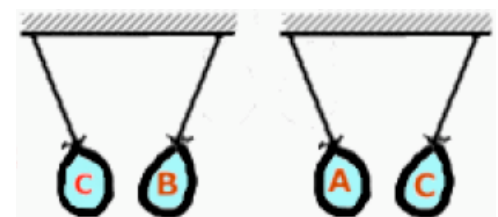
6. Anna Litical is performing a physics lab in which she charges a variety of materials and tests to determine their charge by bringing them near a negatively charged balloon and near some neutral paper bits at rest on the table. Help Anna draw conclusions from her observations by entering +, -, neutral (or a combination of these if absolute conclusiveness is not possible).
- Object A is observed to attract the paper bits; object A must be _____.
 - Object B is observed to attract the balloon; object B must be _____.
 - Object C is observed to repel the balloon; object C must be _____.
 - Object D is observed to attract both the paper bits and the balloon; object D must be _____.
 - Object E is observed to attract the paper bits and repel the balloon; object E must be _____.
7. On three occasions, the following charge interactions between balloons A, B and C are observed. In each case, it is known that balloon B is charged negatively. Based on these observations, what can you conclusively confirm about the charge on balloon A and C for each situation.



Balloon	Conclusive evidence to conclude that the charge is +, -, neutral
A	
B	negative
C	



Balloon	Conclusive evidence to conclude that the charge is +, -, neutral
A	
B	negative
C	



Balloon	Conclusive evidence to conclude that the charge is +, -, neutral
A	
B	negative
C	

8. Jean Yuss is investigating the charge on several objects and makes the following findings.

Object C
attracts B

Object D
repels C

Object E
attracts D
repels F

Object F
attracts A

Jean knows that object A is negatively charged and object B is electrically neutral. What can Jean Yuss definitively conclude about the charge on objects C, D, E, and F? Explain.

Charging by Friction

Read from **Lesson 2** of the **Static Electricity** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/estatics/u8l2a.html>
<http://www.physicsclassroom.com/Class/estatics/u8l1d.html>

MOP Connection: Static Electricity: sublevel 3

Review:

- Fill in the following blanks with the words **electrons** or **protons**.
 _____ are negatively charged and _____ are positively charged. The _____ reside in the nucleus of atoms and are tightly bound; they will never leave an atom as a result of electrostatic procedures. On the other hand, _____ are located outside the nucleus and are easily removed from or added to atoms. As an object begins to gain or lose _____ from its atoms, it becomes positively or negatively charged. A negatively charged object has more _____ than _____. A positively charged object has more _____ than _____.
- During a physics lab, a plastic strip was rubbed with cotton and became positively charged. The correct explanation for why the plastic strip becomes positively charged is that ...
 - the plastic strip acquired extra protons from the cotton.
 - the plastic strip acquired extra protons from the charging process.
 - protons were created as the result of the charging process.
 - the plastic strip lost electrons to the cotton during the charging process.

- Objects differ from one another in terms of their relative tendency to draw electrons towards themselves. Some materials are more *electron-greedy* than others. A **triboelectric series** is a listing of a variety of materials in order of their relative attraction for the electrons of another material. The listing at the right is an example of a triboelectric series. Materials listed near the top of the table have a stronger affinity for electrons than those located below them. When two materials are rubbed together, electrons are transferred from the material that has the lesser affinity for electrons to the material that has the greater affinity for electrons. The object that gains the electrons acquires a _____ (+ or -) charge and the object that loses the electrons acquires a _____ (+ or -).

Triboelectric Series
Celluloid
Sulfur
Rubber
Copper, Brass
Amber
Wood
Cotton
Human Skin
Silk
Cat Fur
Wool
Glass
Rabbit Fur

Use the triboelectric series to answer the following questions:

- When you pull a **cotton** sweater off your **skin**, electrons are transferred from the _____ (cotton, skin) to the _____ (cotton, skin). As a result, your body acquires a _____ (+ , -) charge and the cotton sweater acquires a _____ (+ , -) charge.
- When you rub a **glass** rod with a **silk** cloth, electrons are transferred from the _____ (glass, silk) to the _____ (glass, silk). As a result, the glass rod acquires a _____ (+ , -) charge and the silk cloth acquires a _____ (+ , -) charge.
- Suppose you rub a rubber rod with a silk cloth and a second rubber rod with a wool sweater. The silk cloth will acquire a _____ (+ , -) charge; the wool sweater will acquire a _____ (+ , -) charge. The sweater and the cloth will then be observed to _____ (attract, repel, not interact with) each other.
- Suppose you rub a glass rod with a silk cloth and a second glass rod with rabbit fur. The silk cloth will acquire a _____ (+ , -) charge; the rabbit fur will acquire a _____ (+ , -) charge. The rabbit fur and the silk cloth will then be observed to _____ (attract, repel, not interact with) each other.

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8. Consider the statements below. Identify them as being either True or False.

T or F?	Statement
_____	a. When two objects made of different materials are rubbed together, they each acquire a charge.
_____	b. When two objects made of different materials are rubbed together, they will either be both charged positively or both charged negatively.
_____	c. When two objects made of different materials are rubbed together, they will attract each other after the charging process.
_____	d. When two objects made of different materials are rubbed together, one object gains electrons and the other objects gains protons.
_____	e. When two objects made of different materials are rubbed together, the total amount of charge among the two objects remains unchanged.

9. Saran Wrap has a larger electron affinity than Nylon. If Nylon is rubbed against Saran Wrap, which would end up with the excess negative charge? _____ Explain.

10. Object A is rubbed with object B. Object C is rubbed with object D. Objects A and D are observed to repel each other. Object B is observed to repel a negatively charged balloon. This is conclusive evidence that ...

... object A acquired a _____ (+ , -) charge.

... object B acquired a _____ (+ , -) charge.

... object C acquired a _____ (+ , -) charge.

... object D acquired a _____ (+ , -) charge.

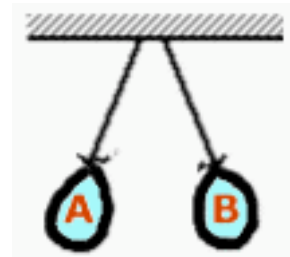


11. A teacher rubs a glass object and a felt cloth together and the glass becomes positively charged. Which of the following statements are true? Circle all that apply.

- a. The glass gained protons during the rubbing process.
- b. The felt became charged negatively during this rubbing process.
- c. Charge is created during the rubbing process; it is grabbed by the more *charge-hungry* object.
- d. If the glass acquired a charge of +5 units, then the felt acquires a charge of -5 units.
- e. This event violates the law of conservation of charge.
- f. Electrons are transferred from glass to felt; protons are transferred from felt to glass.
- g. Once charged in this manner, the glass object and the felt cloth should attract each other.
- h. In general, glass materials must have a greater affinity for electrons than felt materials.

12. Balloons A and B are suspended from the ceiling by light threads; each balloon is made of rubber. Balloon A was rubbed with animal fur. Balloon B was rubbed with animal fur. If a negatively charged plastic tube were inserted between the two balloons, then one would observe that the two balloons _____. (Refer to the triboelectric series.)

- a. would deflect even more from a vertical orientation
- b. would relax to a more vertical orientation
- c. would not be effected at all by the presence of the plastic tube.



Insulators, Conductors and Polarization

Read from **Lesson 1** of the **Static Electricity** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/estatics/u8l1d.html>

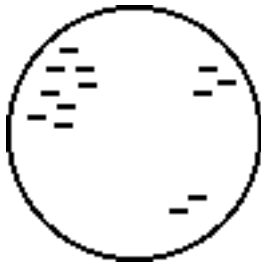
<http://www.physicsclassroom.com/Class/estatics/u8l1e.html>

MOP Connection: Static Electricity: preface to sublevels 5 - 7

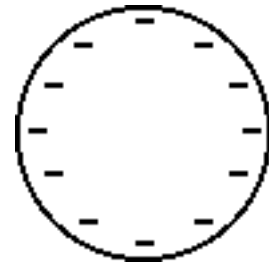
1. Insulators are different than conductors in that insulators _____.
 - a. do not contain electrons or protons
 - b. do not contain any charge
 - c. have a weaker affinity for electrons
 - d. do not allow charge to freely move

2. Materials through which electrons can move readily are classified as _____.
 - a. conductors
 - b. insulators
 - c. semi-conductors

3. The diagram at the right shows a metal sphere attached to the top of an insulating stand. The metal sphere contains an excess of electrons and is thus charged. A student holds various objects in her hand and touches the object to the sphere. Which of the following objects below would allow charge to throw it when the student touches the object to the sphere?
 - a. a plastic straw
 - b. a piece of paper
 - c. a steel house key
 - d. a metal paper clip
 - e. a strip of aluminum foil



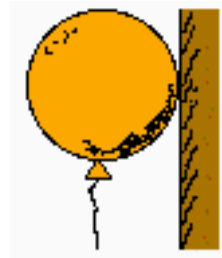
4. Consider these two spheres. They have both been charged. In one case the charge is isolated in three distinct locations; in the other case, the excess charge is even distributed about the surface of the sphere. Which one of these spheres is made of an insulating material and which is made of a conducting material? Label which is which and support your answer with an explanation.



5. **TRUE** or **FALSE**:
 Conductors cannot be charged by frictional rubbing.
 Explain your answer.

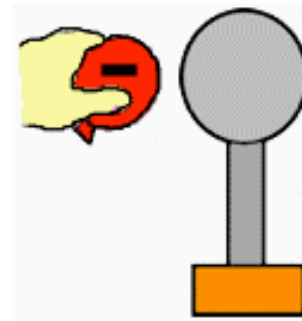
6. A balloon is charged by rubbing it with animal fur. It is then pressed against a wooden cabinet. The balloon and cabinet attract, seeming to defy the force of gravity. This attraction is best explained by _____.
 - a. induction charging of the wood
 - b. frictional charging of the wood
 - c. polarization of wood molecules
 - d. polarization of balloon molecules

7. The above effect (in question #6) is most often noticed of _____.
 - a. conductors
 - b. insulators
 - c. charged objects



Static Electricity

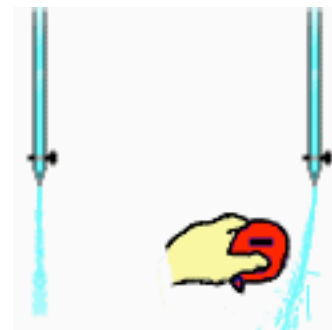
8. A negatively charged balloon is brought near a neutral conducting sphere as shown in the diagram at the right. The presence of the charged balloon will cause something to happen in the sphere. Which of the following would you expect to occur? Select all that apply.



- Electrons in the sphere will move to the balloon.
 - Protons in the sphere will move to the balloon.
 - Electrons in the sphere will move to the left side.
 - Electrons in the sphere will move to the right side.
 - Protons in the sphere will move to the left side.
 - Protons in the sphere will move to the right side.
9. The process of inducing the movement of charge within the sphere (referring to question #8) causes positive and negative charge to be separated. This is known as ____.
- grounding
 - charging
 - polarization
 - induction
10. Charged rubber rods are placed near a neutral conducting sphere, causing a redistribution of charge on the spheres. Which of the diagrams below depict the proper distribution of charge on the spheres? List all that apply.



11. In the above situation (question #10), the conducting sphere is _____. List all that apply.
- charged
 - polarized
 - uncharged (neutral)
12. A physics teacher fills a buret with water and opens the valve, producing a steady stream of water falling vertically to the sink. Then the teacher rubs a rubber balloon with animal fur and holds it near the stream. The stream is observed to deflect from its usual vertical flow towards the balloon. Explain what is causing the deflection of the water stream.



13. A physics teacher charges a balloon negatively by rubbing it with animal fur. The balloon is then placed next to a wooden cabinet and adheres to the cabinet. Explain what is happening at the particle level to cause such a gravity-defying phenomenon. Add to the blown-up view of the diagram to assist in your explanation.



Charging by Conduction and Grounding

Read from **Lesson 2** of the **Static Electricity** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/estatics/u8l2b.html>

<http://www.physicsclassroom.com/Class/estatics/u8l2d.html>

MOP Connection: Static Electricity: sublevel 4

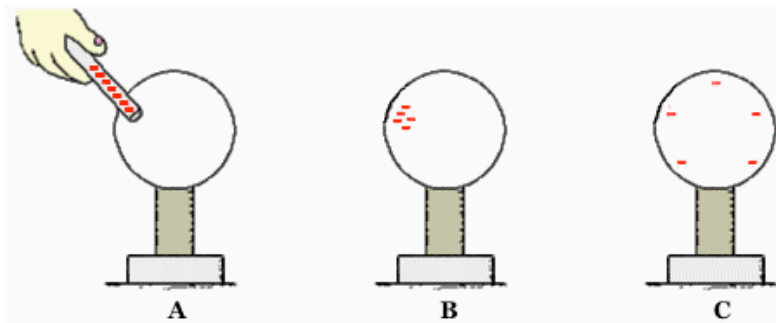
Review:

1. Fill in the following blanks with the words **electrons** or **protons**.

_____ are negatively charged and _____ are positively charged. The _____ reside in the nucleus of atoms and are tightly bound; they will never leave an atom as a result of electrostatic procedures. On the other hand, _____ are located outside the nucleus and are easily removed from or added to atoms. As an object begins to gain or lose _____ from its atoms, it becomes positively or negatively charged. A negatively charged object has more _____ than _____. A positively charged object has more _____ than _____.

2. A metal sphere is resting upon an insulating stand. A teacher holds a metal bar (with an insulating handle). The teacher uses the metal bar to charge the metal sphere by **conduction**. Which one of the processes describes what the teacher likely did to charge the sphere by conduction?
- The teacher rubbed the bar and the sphere together.
 - The teacher held the bar near the sphere and then touched the sphere with her hand.
 - The teacher charged the bar and then contacted it to the sphere.

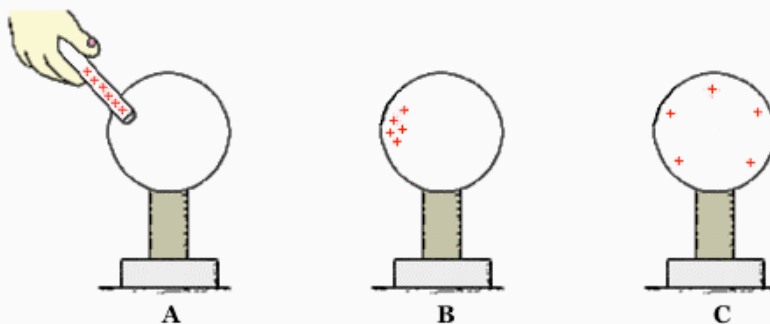
Consider the conduction charging process described below:



- A: A teacher holds a negatively charged metal bar by its insulating handle and touches it to a metal sphere (attached to an insulating stand).
 B: The teacher pulls the metal bar away and the metal sphere acquires a charge.
 C: The excess negative charge spreads uniformly about the surface of the metal sphere.
3. Diagram A is the charging step. How does the sphere become charged?
- Electrons move from the insulating stand into the sphere.
 - Electrons move from the charged metal bar into the sphere.
 - Protons move from the sphere into the negatively charged bar.
4. When the metal bar is pulled away in Diagram B, the metal bar is _____.
 - positively charged
 - electrically neutral
 - still negatively charged, but has fewer excess electrons than it previously did.
5. Diagram C shows the excess negative charge distributed differently than it is in Diagram B. Explain why the excess negative charge would distribute itself as it does in Diagram C.

Static Electricity

Now consider the conduction charging of the sphere using a positively charged metal bar:



- A: A teacher holds a positively charged metal bar by its insulating handle and touches it to a metal sphere (attached to an insulating stand).
B: The teacher pulls the metal bar away and the metal sphere acquires a charge.
C: The excess positive charge is spread uniformly about the surface of the metal sphere.

6. Diagram A is the charging step. How does the sphere become charged?
- Protons move from the insulating stand into the sphere.
 - Protons move from the charged metal bar into the sphere.
 - Electrons move from the sphere into the positively charged bar.
7. When the metal bar is pulled away in Diagram B, the metal bar is ____.
- negatively charged
 - electrically neutral
 - still positively charged, but has fewer excess protons than it previously did.

Two different processes are shown in the diagrams below:



- A: A negatively charged metal sphere is touched.
B: The hand is pulled away and the sphere is then electrically neutral.
- A: A positively charged metal sphere is touched.
B: The hand is pulled away and the sphere is then electrically neutral.
8. The process of neutralizing the charged spheres as depicted above is known as ____.
- charging
 - polarization
 - induction
 - grounding
9. When the negatively charged sphere is touched, _____ move from the _____ to the _____.
- electrons, sphere, hand
 - electrons, hand, sphere
 - protons, sphere, hand
 - protons, hand, sphere
10. When the positively charged sphere is touched, _____ move from the _____ to the _____.
- electrons, sphere, hand
 - electrons, hand, sphere
 - protons, sphere, hand
 - protons, hand, sphere

Charging by Induction

Read from **Lesson 2** of the **Static Electricity** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/estatics/u8l2c.html>

MOP Connection: Static Electricity: sublevels 5, 6, and 7

Review:

1. Fill in the following blanks with the words **electrons** or **protons**.

_____ are negatively charged and _____ are positively charged. The _____ reside in the nucleus of atoms and are tightly bound; they will never leave an atom as a result of electrostatic procedures. On the other hand, _____ are located outside the nucleus and are easily removed from or added to atoms. As an object begins to gain or lose _____ from its atoms, it becomes positively or negatively charged. A negatively charged object has more _____ than _____. A positively charged object has more _____ than _____.

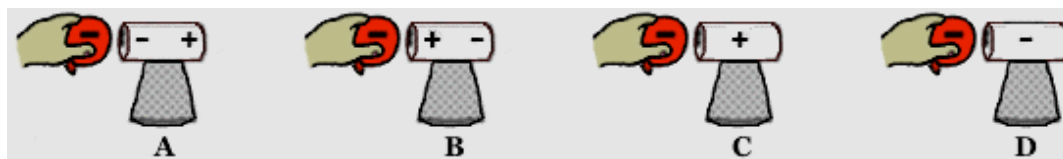
Consider the following process:

An uncharged metal pop can is attached to a Styrofoam cup (which acts as an insulating stand). A negatively charged balloon is brought near the pop can. While the balloon is held near, the can is touched. When the can is pulled away, the pop can is charged.



2. This process is known as _____.

a. charging by conduction	b. charging by induction
c. polarization	d. grounding
3. When the balloon is held near to the pop can (and before being touched by the hand), the distribution of charge on the pop can is best depicted by diagram _____.



4. When the pop can is touched by the hand, _____ move from the _____ to the _____.

a. protons, hand, can	b. protons, can, hand
c. electrons, hand, can	d. electrons, can, hand
5. This process causes the can to acquire a _____ charge.

a. negative	b. positive	c. neutral
-------------	-------------	------------
6. When the induction charging process is complete, the balloon is _____.

a. positively charged	b. electrically neutral
c. still negatively charged, only having fewer excess electrons as before the process began	
d. still negatively charged, having the same amount of negative charge as it previously had	
7. In general, the use of a negatively charged object to charge another object by induction causes the other object to acquire a _____ charge.

a. positive	b. negative
-------------	-------------

Static Electricity

Now consider a similar process:

An uncharged metal pop can is attached to a Styrofoam cup (which acts as an insulating stand). A positively charged balloon is brought near the pop can. While the balloon is held near, the can is touched. When the can is pulled away, the pop can is charged.

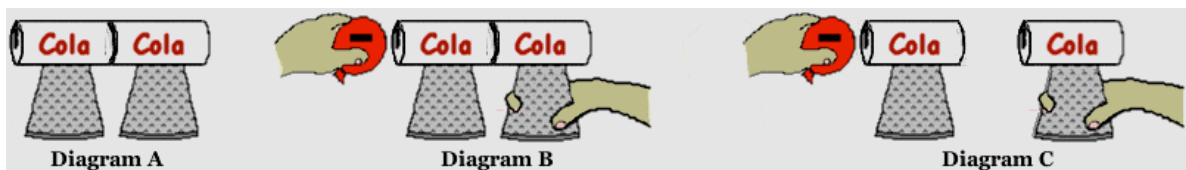


8. When the balloon is held near to the pop can (and before being touched by the hand), the distribution of charge on the pop can is best depicted by diagram _____.



9. When the pop can is touched by the hand, _____ move from the _____ to the _____.
- protons, hand, can
 - protons, can, hand
 - electrons, hand, can
 - electrons, can, hand
10. This process causes the can to acquire a _____ charge.
- negative
 - positive
 - neutral

In the above induction charging processes, there are two basic steps: a **polarization step** and a **charging step**. In the charging step, the hand serves as a **ground** - an object that serves as a seemingly infinite source of or sink for electrons. During the charging step, electrons move into or out of the ground (hand) in order to charge the pop can. Another means of charging the pop can involves the use of another conducting object. For instance, another pop can could be used. The diagrams below depict the induction charging process using a second pop can in place of the hand.



11. In terms of electron movement, explain what is happening in Diagrams B and C above. Finally, state the charge acquired by the left and the right can as a result of this process.

Coulomb's Law

Read from **Lesson 3** of the **Static Electricity** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/estatics/u8l3b.html>

<http://www.physicsclassroom.com/Class/estatics/u8l3c.html>

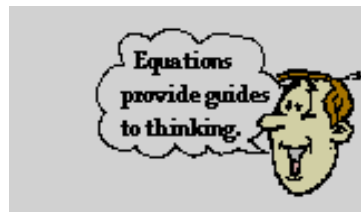
<http://www.physicsclassroom.com/Class/estatics/u8l3d.html>

MOP Connection: Static Electricity: sublevels 8 and 9

Coulomb's Law can be states in equation form as

$$F = \frac{k Q_1 Q_2}{d^2}$$

This equation can be used as an *algebraic recipe* for solving computational problems or as a *guide to thinking* about how an alteration in the quantity of charge or the distance between charged objects effects the amount of attractive or repulsive force.



Using Coulomb's Law as a "Guide to Thinking"

Alteration in the Quantity of Charge

- _____ 1. Two charged objects have a repulsive force of .080 N. If the charge of one of the objects is doubled, then what is the new force?
- _____ 2. Two charged objects have a repulsive force of .080 N. If the charge of both of the objects is doubled, then what is the new force?

Alteration in the Distance between Charged Objects

- _____ 3. Two charged objects have a repulsive force of .080 N. If the distance separating the objects is doubled, then what is the new force?
- _____ 4. Two charged objects have a repulsive force of .080 N. If the distance separating the objects is tripled, then what is the new force?
- _____ 5. Two charged objects have an attractive force of .080 N. If the distance separating the objects is quadrupled, then what is the new force?
- _____ 6. Two charged objects have a repulsive force of .080 N. If the distance separating the objects is halved, then what is the new force?

Alteration in both the Quantity of Charge and the Distance

- _____ 7. Two charged objects have a repulsive force of .080 N. If the charge of one of the objects is doubled, and the distance separating the objects is doubled, then what is the new force?
- _____ 8. Two charged objects have a repulsive force of .080 N. If the charge of both of the objects is doubled and the distance separating the objects is doubled, then what is the new force?
- _____ 9. Two charged objects have an attractive force of .080 N. If the charge of one of the objects is increased by a factor of four, and the distance separating the objects is doubled, then what is the new force?
- _____ 10. Two charged objects have an attractive force of .080 N. If the charge of one of the objects is tripled and the distance separating the objects is tripled, then what is the new force?

Static Electricity

Using Coulomb's Law as an "Algebraic Recipe"

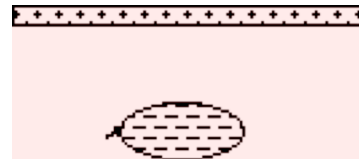
11. A balloon with a charge of 4.0×10^{-5} C is held a distance of 0.10 m from a second balloon having the same charge. Calculate the magnitude of the repulsive force. **PSYW**

12. Calculate the electrical force (in Newtons) exerted between a 22-gram balloon with a charge of $-2.6 \mu\text{C}$ and a wool sweater with a charge of $+3.8 \mu\text{C}$; the separation distance is 0.75 m. (NOTE: a μC or microCoulomb is a unit of charge; $10^6 \mu\text{C} = 1 \text{ C}$) **PSYW**

13. Suppose that two equally charged spheres attract each other with a force of -0.492 N ("-" means attractive) when placed a distance of 29.1 cm from each other. Determine the charge of the spheres. **PSYW**

14. A $+5.0 \mu\text{C}$ charge and a $-6.0 \mu\text{C}$ charge experience an attractive force of -0.72 N ("-" means attractive). Determine their separation distance. **PSYW**

15. A balloon has been rubbed with wool to give it a charge of -1.0×10^{-6} C. A plastic tube with a charge of $+4.0 \times 10^{-6}$ C is held a distance of 0.50 m above the balloon. Determine the electrical force of attraction between the tube and the balloon. **PSYW**



In the space at the right, construct a free-body diagram showing the direction and the type of all forces acting upon the 30.0-gram balloon.



Will the balloon accelerate up, down, or not at all? _____

If there is an acceleration, then calculate its value. (Assume that the plastic tube is held a constant distance of 0.5 m from the balloon.) **PSYW**

Electric Field

Read from Lesson 4 of the Static Electricity chapter at The Physics Classroom:

<http://www.physicsclassroom.com/Class/estatics/u8l4a.html>

<http://www.physicsclassroom.com/Class/estatics/u8l4b.html>

MOP Connection: Static Electricity: sublevels 10 and 11

- The standard metric units of measurements for electric field strength are _____.
- The direction of the electric field vector is defined as _____.

Use the electric field equations to answer the following questions.

- A test charge of $+1.0 \times 10^{-6}$ C experiences a force of 0.050 N. The electric field strength is _____.
- A test charge of $+1.0 \times 10^{-6}$ C experiences a force of 0.10 N. The electric field strength is _____.
- An object with a charge of 2.0×10^{-4} C creates an electric field. A test charge of $+1.0 \times 10^{-6}$ C experiences a force of 0.050 N. The electric field strength is _____.
- An object with a charge of 2.0×10^{-4} C creates an electric field. A test charge of $+2.0 \times 10^{-6}$ C experiences a force of 0.10 N. The electric field strength is _____.
- An object with a charge of 4.0×10^{-4} C creates an electric field. A test charge of $+1.0 \times 10^{-6}$ C experiences a force of 0.10 N. The electric field strength is _____.

- An object with a charge of **Q** creates an electric field. A positive test charge, **q**, is used to test the strength of the field. Use this scenario to answer the following questions:



- If the charge of the test charge **q** is doubled, then it will experience _____ (2X, 4X, 1/2, 1/4-th, the same) force; the electric field strength at this location will be _____ (2X, 4X, 1/2, 1/4-th, the same as) the original value.
 - If the charge of the object **Q** is doubled, then the test charge will experience _____ (2X, 4X, 1/2, 1/4-th, the same) force; the electric field strength at this location will be _____ (2X, 4X, 1/2, 1/4-th, the same as) the original value.
 - If the distance between the charge and the test charge is doubled, then the test charge will experience _____ (2X, 4X, 1/2, 1/4-th, the same) force; the electric field strength at this location will be _____ (2X, 4X, 1/2, 1/4-th, the same as) the original value.
- Use your understanding of electric force and electric field to fill in the following table.

	Charge creating the E field (C)	Charge used to test the E field (C)	Force experienced by test charge (N)	Electric Field Intensity (N/C)	Distance (fictional units)
a.	4.0×10^{-4} C	1.0×10^{-6} C	0.20 N		d
b.	4.0×10^{-4} C	2.0×10^{-6} C		2.0×10^5 N/C	d
c.	8.0×10^{-4} C	1.0×10^{-6} C	0.40 N		d
d.	8.0×10^{-4} C	2.0×10^{-6} C		4.0×10^5 N/C	d
e.	8.0×10^{-4} C		0.60 N		d
f.	8.0×10^{-4} C	1.0×10^{-6} C		1.0×10^5 N/C	2d
g.	8.0×10^{-4} C	2.0×10^{-6} C			2d
h.	8.0×10^{-4} C		0.10 N		2d
i.	4.0×10^{-4} C			8.0×10^5 N/C	0.5 d
j.	4.0×10^{-4} C				0.5 d

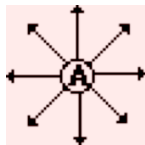
Electric Field Lines

Read from **Lesson 4** of the **Static Electricity** chapter at **The Physics Classroom**:

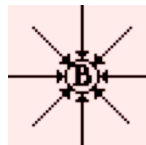
<http://www.physicsclassroom.com/Class/estatics/u8l4c.html>
<http://www.physicsclassroom.com/Class/estatics/u8l4d.html>

MOP Connection: Static Electricity: sublevel 12

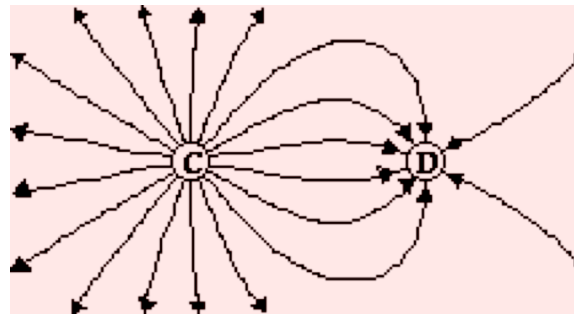
1. Electric field lines begin on _____ (+, -) charges or at infinity and terminate on _____ (-, +) charges or infinity. The number of lines that emanate from a charge or approach a charge depends upon _____. At locations where a line meets the surface of a charge, the lines are drawn in a _____ (tangent, radial) direction. The strength of the electric field is _____ (smallest, greatest) wherever the lines are closest together.
2. Use your understanding of electric field lines to identify the charges on the objects in the following configurations.



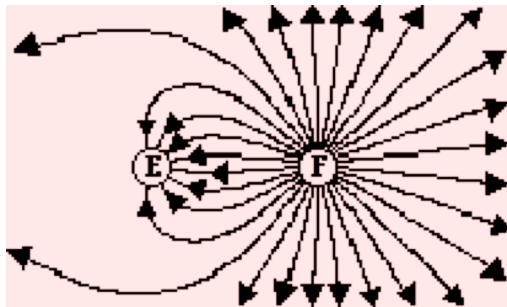
A: + or -



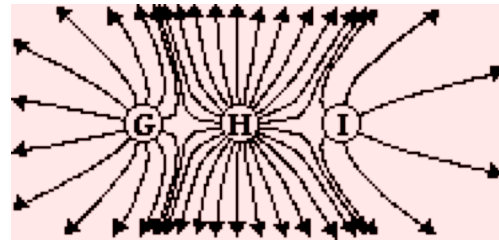
B: + or -



C: + or - D: + or -

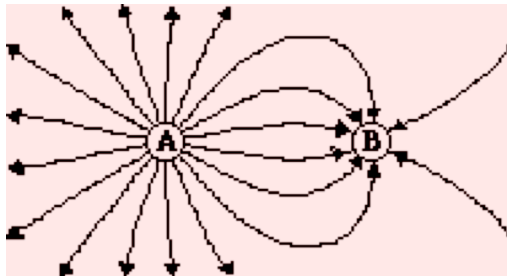


E: + or - F: + or -

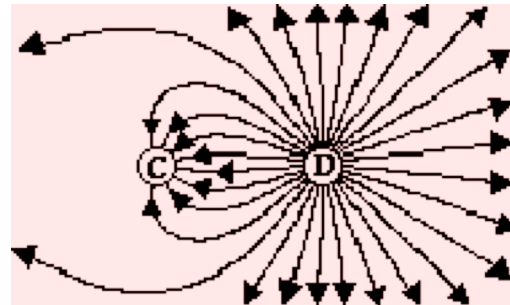


G: + or - H: + or - I: + or -

3. Observe the electric field lines below for various configurations. Rank the objects according to which has the greatest magnitude of electric charge, beginning with the smallest charge.

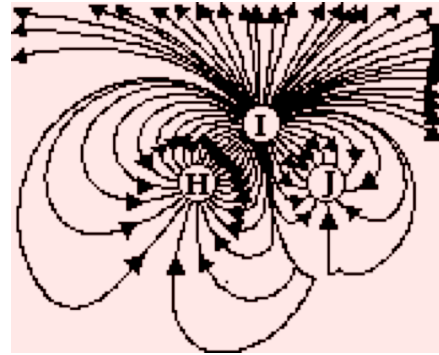
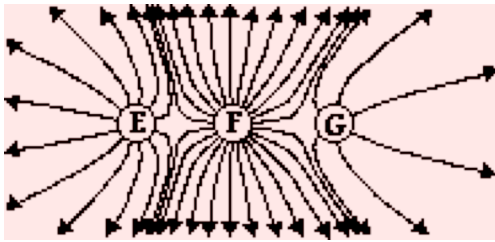


Ranking: _____ < _____



Ranking: _____ < _____

Static Electricity



Ranking: _____ < _____ < _____ Ranking: _____ < _____ < _____

4. Draw the electric field lines for the following configurations of charges. Place arrows upon your electric field lines.
