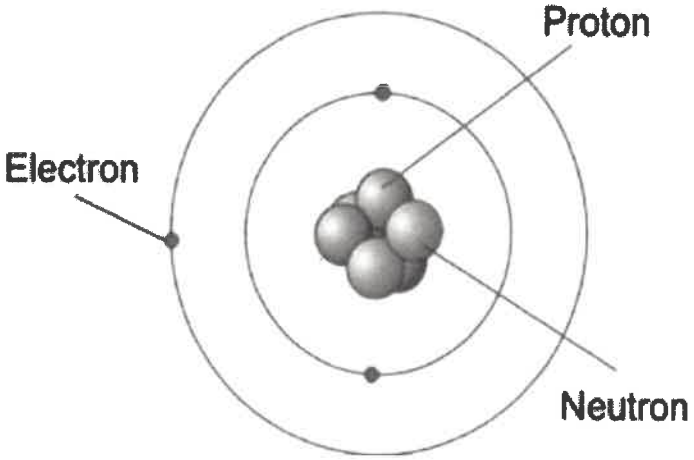
Chapter 8: Static Electricity

6.1 Electrical Structure of Matter

Bohr-Rutherford Model:

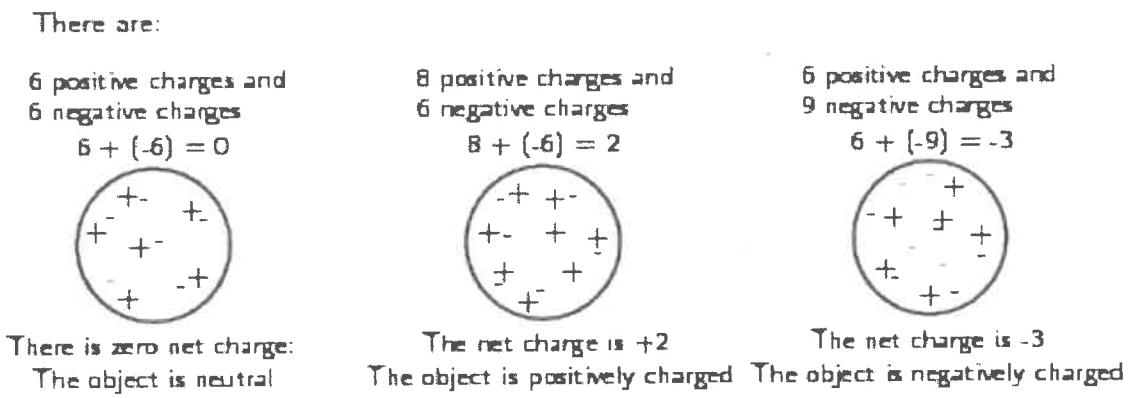
- Matter is composed of particles called atoms
  - Protons:
    - found in the nucleus
    - small, heavy particles
    - positively charged
  - Electrons:
    - Move in the space around the nucleus
    - Small and light (about 1/2000th mass of a proton)
    - negatively charged
  - Neutrons:
    - Found in nucleus
    - Small heavy particles
    - Do not carry a charge

- Atoms are normally electrically neutral - equal number of protons and electrons



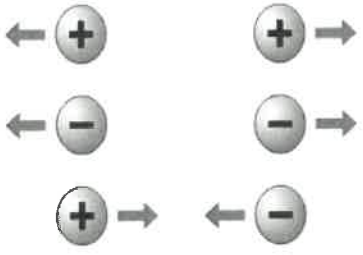
Electrostatics

- Atoms of a solid are held in place
- Nuclei vibrate but are not free to move, therefore the positive charge remains fixed
- Outermost electrons can move from atom to atom, causing charges to form.
- Whenever electrons are added or removed from a solid, it becomes charged
  - When electrons are removed – object becomes positively charged
  - When electrons are added – object becomes negatively charged



Rules of Static Charge

- Objects with like charges repel each other
- Objects with unlike charges attract one another
- Charged objects attract neutral objects



Law of Conservation of Charge

- the net charge of an isolated system remains constant

- Charge is 'quantized', meaning that charge comes in integer multiples of the elementary charge, e
  - A proton has a charge of +e, while the electron has a charge of -e.

- In the early 20th century, R. Millikan found the smallest unit of charge:

  $e = -1.60 \times 10^{-19}$ C where C is the unit of charge, Coulomb
  (negative since each electron has a negative charge)

  or

  $1\ C = 6.24 \times 10^{18}$ e.

- The charge on an object, then can be calculated by using the formula:

  $Q = Ne$

  where Q = electric charge
  N = excess number of electrons or protons (+ if excess, − if deficit)
  e = charge of a single proton or electron (1.6×10^{-19} C)

Ex. 1 How many electrons have been removed from a positively charged pith ball electroscope if it has a charge of 7.5×10^{-11} C?

$Q = 7.5 \times 10^{-11} C$
$e = -1.60 \times 10^{-19} C/e$
$N = ?$

$Q = Ne$

$N = \frac{Q}{e} = \frac{7.5 \times 10^{-11} C}{1.60 \times 10^{-19} C/e} = -4.7 \times 10^{8}$ electrons

or 4.7×10^{8} e removed

Ex. 2 What is the charge, in coulombs, on an object that has:

a) An excess of 6.25×10^{19} electrons?

$Q = ?$
$e = -1.60 \times 10^{-19} C/e$
$N = +6.25 \times 10^{19} e$

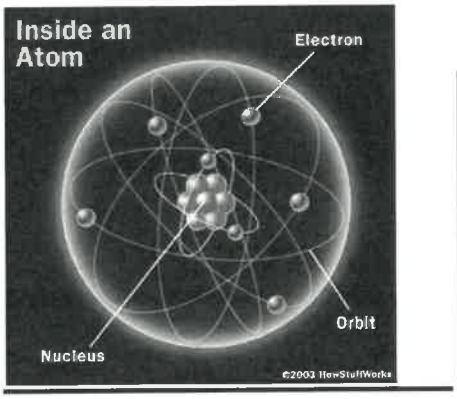
$Q = Ne = (6.25 \times 10^{19} e)(-1.60 \times 10^{-19} C/e)$
$= -10.0 C$

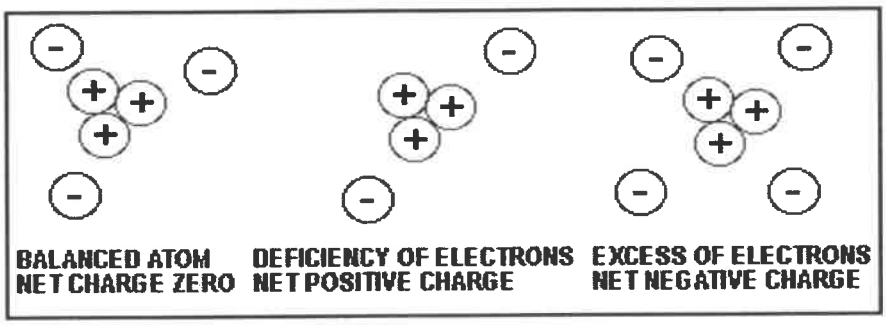
b) A deficiency of 1.0×10^{8} electrons?

$Q = ?$
$e = -1.60 \times 10^{-19} C/e$
$N = -1.0 \times 10^{8} e$

$Q = Ne = (-1.0 \times 10^{8} e)(-1.60 \times 10^{-19} C/e)$
$= +1.6 \times 10^{-11} C$

Electrostatics - Charging objects





There are two types of charges. They are positive and negative charges.

- Negative charges are created when electrons are added.
- Positive charges are created when electrons are lost.

The total charge on any object can be found by knowing the number of excess or deficient electrons on that object.

The charge of an electron is $e = -1.6 \times 10^{-19} C$.

The total charge on an object is given by **$Q = ne$**

where Q is the total charge in Coulombs, n is the number of electrons and e is the charge of an electron.

Protons have the same charge as the electrons. Except that they are positively charged.

1. We will NEVER TALK about PROTON motion. Explain why not?

   Protons are locked inside the nucleus + cannot flow

2. A neutral metal plate loses some electrons. It is now positive (type of charge). This is because electrons that are lost have negative charge.

3. A pop-can rubbed with fur will be negative (Type of charge). This is because electrons are added to it.

4. Find the charge on a metal plate that has 500 excess electrons.

$Q = ?$
$N = +500e$
$e = -1.6 \times 10^{-19} C$

$Q = Ne$
$= (+500e)(-1.6 \times 10^{-19} C/e)$
$= -8.0 \times 10^{-17} C$

5. Find the number of excess electrons on pith ball that has a charge of -1.2C.

$Q = -1.2C$
$N = ?$
$e = -1.6 \times 10^{-19} C$

$Q = Ne$
$N = \frac{Q}{e} = \frac{-1.2C}{-1.6 \times 10^{-19} C} = +7.5 \times 10^{18} C$

6. An electroscope has a total of 2.0×10^6 electrons and 1.8×10^6 protons. What is the net charge on the electroscope?

$N = \#p - \#e$
$= 1.8 \times 10^6 - 2.0 \times 10^6$
$= -2 \times 10^5 e$ (deficit)
$e = -1.6 \times 10^{-19} C/e$
$Q = ?$

$Q = Ne$
$= (-2 \times 10^5 e)(-1.6 \times 10^{-19} C/e)$
$= 3.2 \times 10^{-14} C$
or $3 \times 10^{-14} C$

7. One atom of Gold carries 79 protons in the nucleus. 79 electrons orbit this nucleus.

A. Determine the net charge on one atom of gold.

neutral... no charge

B. Determine the net charge of the 79 protons in the nucleus of this atom.

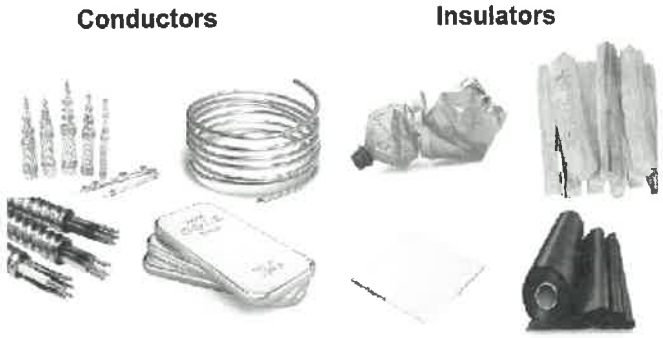
$Q = ?$
$N = 79$ protons
$e = +1.6 \times 10^{-19} C/\text{proton}$.

$Q = Ne$
$= (79)(+1.6 \times 10^{-19} C/\text{proton})$
$= 1.264 \times 10^{-17} C$
$= 1.3 \times 10^{-17} C$

Answers: 1) Protons are fixed; 2) positive, negative 3) negative, electrons 4) $-8.0 \times 10^{-17} C$ 5) 7.5×10^{18} e 6) $-3.2 \times 10^{-14} C$ 7) a) 0 C b) $1.4 \times 10^{-17} C$ FIX

Electrostatic Charging

- Most objects are electrically neutral; they have equal amounts of positive and negative charge
- Solids in which charge flows freely are called conductors (i.e., most metals)
    - Outermost electrons in the atoms are so loosely bound to their atoms that they are free to move around
- Solids which resist the flow of charge are called insulators (plastic, cork, glass, wood, rubber)
    - Electrons are tightly bound to the atoms and are not free to flow

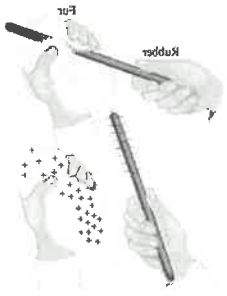


Charges can be transferred from one object to another through:

1) Friction:

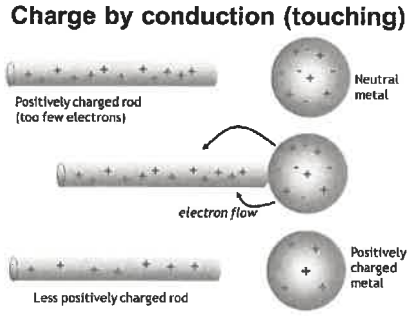
- If you rub one material with another, electrons have a tendency to be transferred from one material to another

    Ex., glass with silk, PVC rod with fur



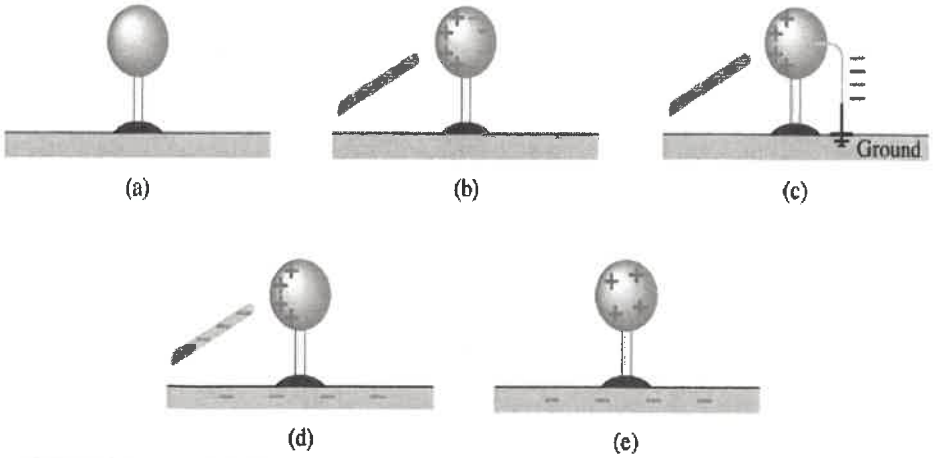
2) Conduction:

- If a charged object touches a conductor, some charge will flow between the object and the conductor, sharing the charge with the conductor.



3) Induction

- charged object is brought close to the conductor, but does not touch.
- If the conductor is grounded (touching anything that can give up or take electrons), electrons will either flow onto the conductor or away from it.
- When the ground connection is removed, the conductor will then have a charge opposite in sign to that of the charged object.



Electrostatics Concepts

1. What are the similarities and differences between the properties of an electron and a proton?

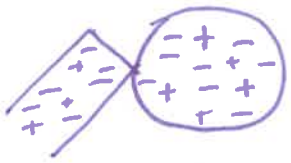
- Both have same quantity of charge / within an atom
- different types of charge (e = negative, p = positive)
- electrons can flow in conductors

2. Describe the difference between a positively-charged object and a negatively-charged object, in terms of electrons.

positively charged = deficit of electrons

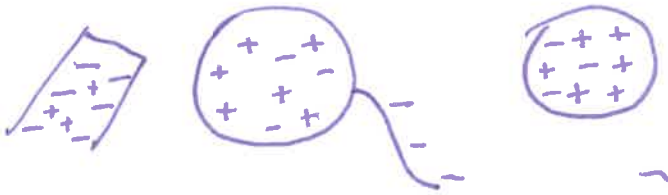
negatively charged = excess electrons

3. Draw a diagram to show how an object can take on a negative charge using only a negatively-charged vinyl strip.



If a negatively-charged strip comes into contact with an object, the charge will be shared as excess electrons flow into the object (conduction)

4. Draw a series of diagrams to show how an object can take on a positive charge using only a negatively-charged vinyl strip.



Negatively charged strip repels electrons in the object, causing electrons to flow to ground. If grounding is removed, the object is then left with a deficit of electrons (induction)

5. Why do clothes sometimes have static on them as soon as they come out of the clothes dryer?

As different fabrics rub against each other, electrons are transferred from one object to another, leaving the clothes items charged.

6. A charged rod is brought near a pile of tiny plastic spheres. The spheres are attracted to the charged rod and then fly off the rod. Why does this happen?

As the rod approaches the spheres, electrons move in the sphere away from the rod, inducing an opposite charge + causing the rod to attract the spheres. Once they come into contact, electrons are conducted to the spheres, so they now have like charges + repel.

7. The electrostatic series lists various objects according to how tightly they hold their electrons. What will be the charge on a silk scarf if it is rubbed with glass? With plastic wrap?

Silk holds more tightly ∴ will be negative + glass will be positive

Plastic wraps holds electrons more tightly than silk ∴ plastic will be negative + silk positive.

Hold electrons tightly
-
vinyl
plastic wrap
amber
cotton
paper
silk
fur
wool
glass
hands
+
Hold electrons loosely

8. Outline a method by which you could determine (with certainty) whether the charge on your comb after you comb your hair is positive or negative.

Rub a vinyl strip with fur so it becomes negatively charged. If the vinyl strip is attracted to the comb, the comb is +'ively charged; if it repels, the comb is also negative.

CHAPTER 6 REVIEW: STATIC ELECTRICITY

1. Describe what happens when the following charged objects interact:

Object #1	Object #2	Attract/Repel/Neither
+	+	Repel
+	-	attract
+	0	attract
-	-	repel
-	0	attract
0	0	neither

2. Explain (in detail!) why a wooden metre stick will move towards a positively-charged acetate strip. Include a diagram in your explanation.

If a positively-charged strip approaches a neutral metre stick, electrons in the wood will flow towards the strip, inducing a negative charge in that part of the metre stick. The positive strip will then attract the temporarily negatively-charged part of the metre stick, causing it to move

3. A vinyl strip is rubbed by a piece of fur, transferring electrons from the fur to the vinyl strip. You then touch a pop can lying on its side with the vinyl strip. If another charged vinyl strip is brought close to the can, what do you expect will happen?

- Vinyl rubbed with fur becomes negatively charged
- If the vinyl touches the can, electrons will conduct from the strip to the can, making it negatively-charged too.
- If any strip is brought close, the two negatively-charged objects should repel each other + the can should roll away.

4. Find the charge on a pith ball if it has 5.0×10^3 excess electrons.

$Q = ?$
$N = +5000e$
$e = -1.6 \times 10^{-19} C/e$

$Q = Ne$
$= (5000e)(-1.6 \times 10^{-19} C/e)$
$= -8.0 \times 10^{-16} C$

-8.0×10^{-16} C *

5. Determine the net charge of a nitrogen nucleus (atomic number = 7).

$Q = ?$
$N = 7p^+$
$e = +1.6 \times 10^{-19} C/p$

$Q = Ne$
$= (7p)(1.6 \times 10^{-19} C/p) = 1 \times 10^{-18} C$

1×10^{-18} C

Chapter 9: Current Electricity

Flow of Charge

- Charge can move from one object to another through a conductor
- Electric current: when a charge moves, or 'flows' from one place to another
- In metals, moving charges have a negative charge:

$I = Q/t$ Q = total charge flowing past a point in a circuit

t = time over which charge flowed

I = current (units: Amperes)

1 A = the electric current flowing when 1 C of charge moves past a point in a conductor in 1 s.

Ex.1: Calculate the current in an electric toaster if it takes 9.0×10^2 C of charge to toast 2 slices of bread in 1.5 min.

$Q = 9.0 \times 10^2 C$

$t = 1.5 min \times \frac{60s}{1 min} = 90s$

$I = ?$

$I = \frac{Q}{t}$

$= \frac{900C}{90s}$

$= 10A$ or $1.0 \times 10^1 C$

Ex. 2: A light bulb with a current of 0.80 A is left burning for 25 minutes. How much electric charge passes through the filament of the bulb?

$I = 0.80A$

$t = 25 min \times \frac{60s}{1 min} = 1500s$

$Q = ?$

$I = \frac{Q}{t}$

$Q = I \cdot t$

$= (0.80A)(1500s)$

$= 1200C$