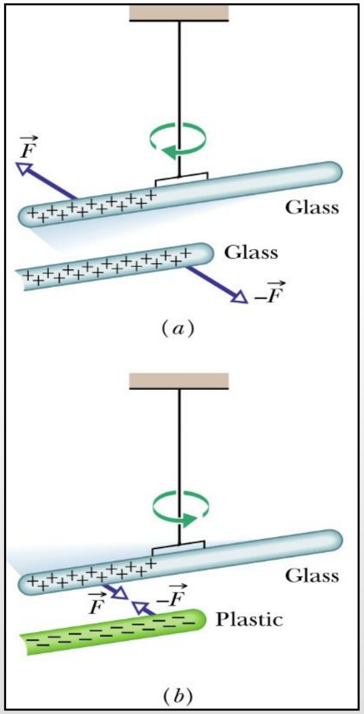
College of Science

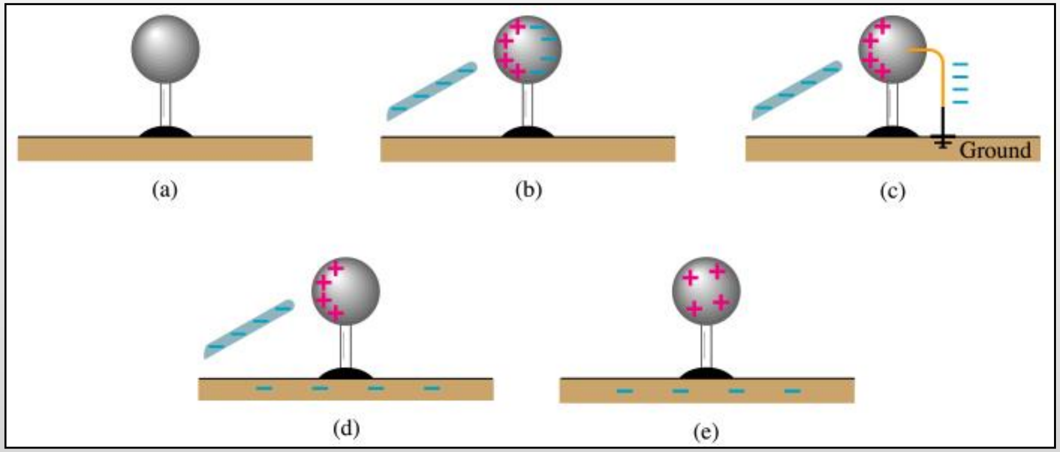
Physics Department

1st Year Students

Electricity

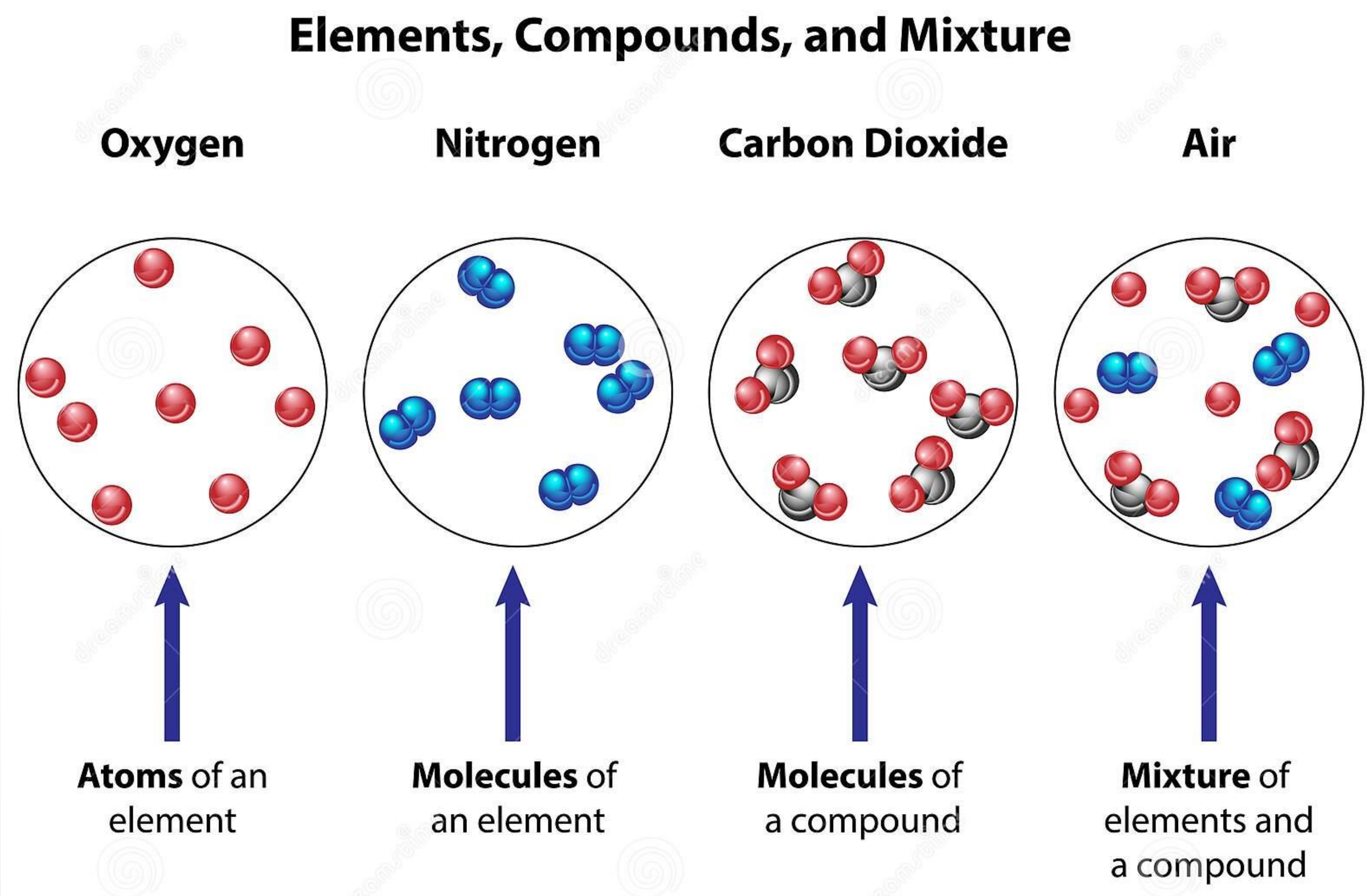
Static electricity





By: Dr. Nasih Hawramy

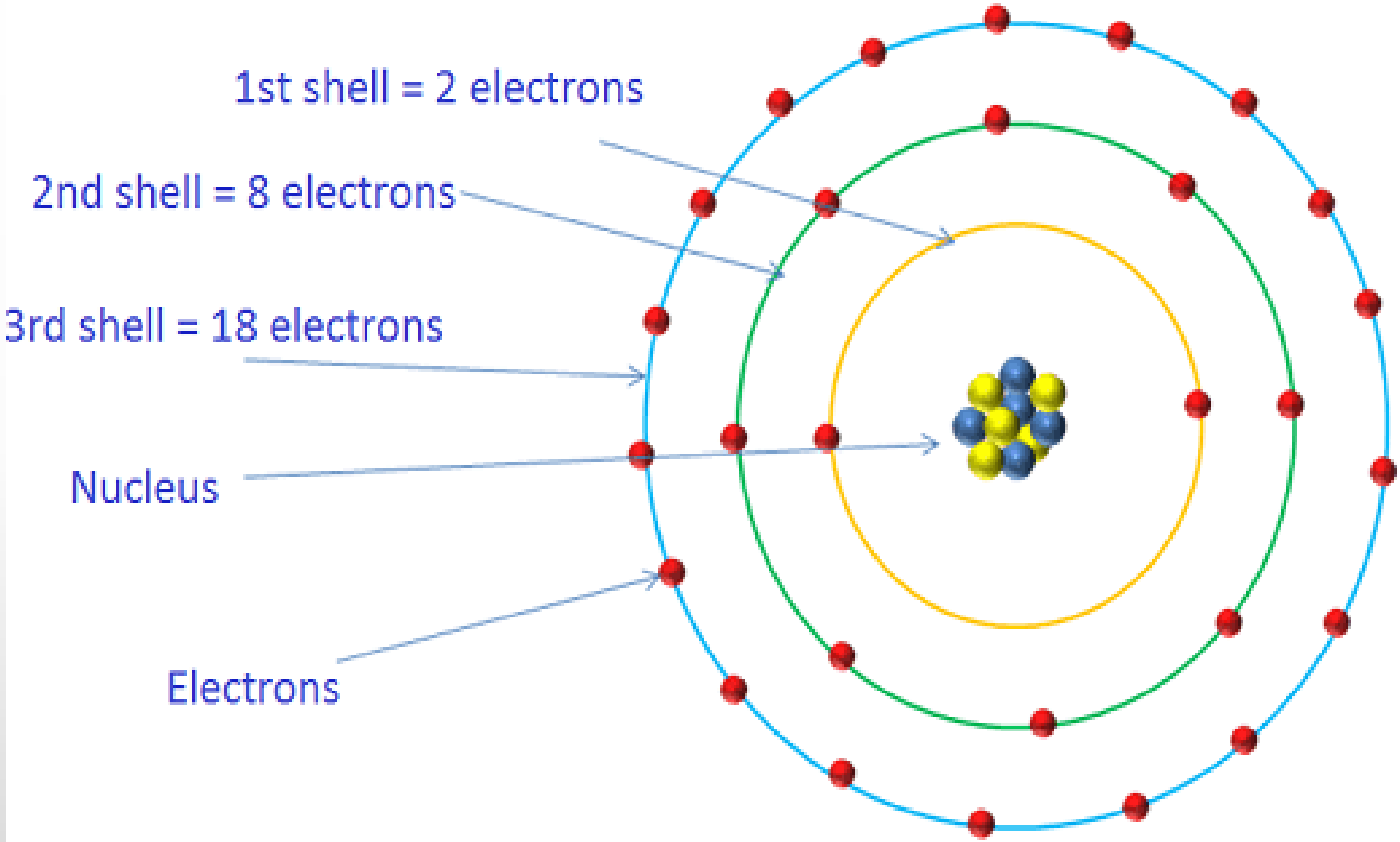
2023 -2024


Elements, Compounds, and Mixture
Oxygen
Nitrogen
Carbon Dioxide
Air
Atoms of an element
Molecules of an element
Molecules of a compound
Mixture of elements and a compound

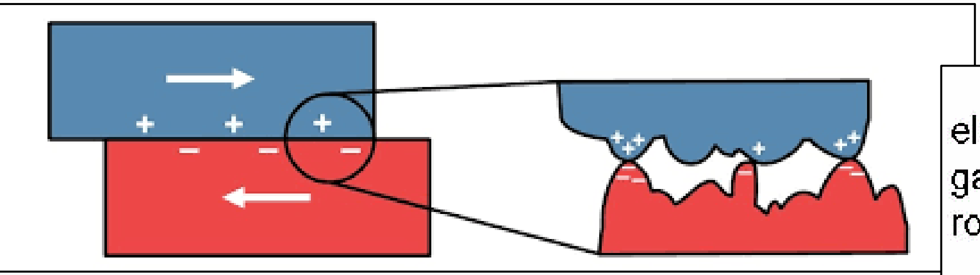
Atoms are composed of subatomic particles of ***electrons, protons,*** and ***neutrons*** in various combinations. The electron is the fundamental negative charge (-) of electricity. Electrons revolve (spin) about the nucleus or centre of the atom in paths of concentric (circles and rings that have the same centre) "shells," or ***orbits***.

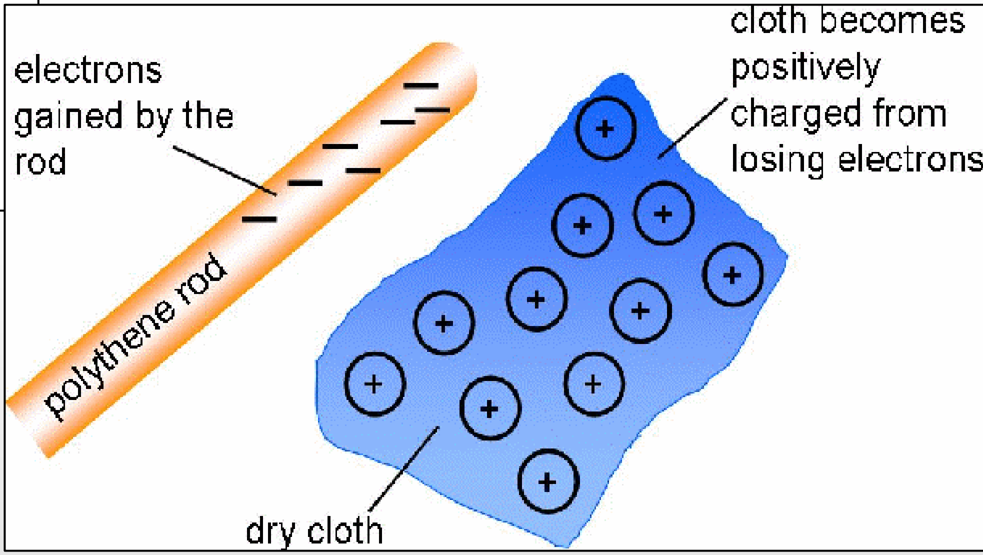
particle	charge (C)	mass (Kg)
proton p^+	$+1.602 \times 10^{-19}$	1.67×10^{-27}
neutron n^0	0	1.67×10^{-27}
electron e^-	-1.602×10^{-19}	9.11×10^{-31}

The **proton** is the fundamental positive (+) charge of electricity. Protons are found in the nucleus. The number of protons within the nucleus of any particular atom specifies the **atomic number** of that atom. For example, **the silicon atom has 14 protons** in its nucleus. So, the atomic number of silicon is 14. The **neutron**, which is the fundamental neutral charge of electricity, is also found in the nucleus.


1st shell = 2 electrons
2nd shell = 8 electrons
3rd shell = 18 electrons
Nucleus
Electrons

In its natural (usual) state, an atom of any element contains an equal number of electrons and protons. Since the negative (-) charge of each electron is equal in magnitude to the positive (+) charge of each proton, the two opposite charges cancel. An atom in this condition is **electrically neutral**, or **in balance**.





silk

fur

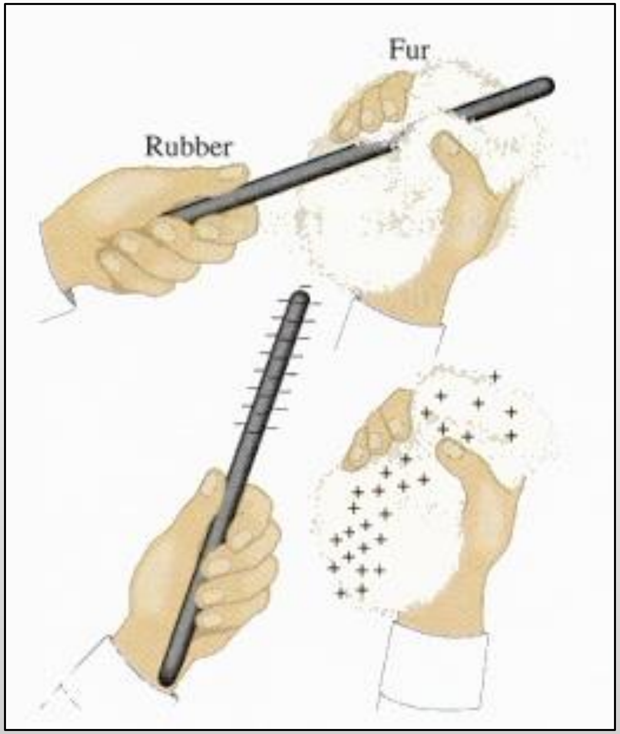
Common examples of static electricity in action are static cling, fly-away hair and the sparks that can occur when you touch something.

Charging up Objects

Charging implies either **adding electrons** to an object, **removing electrons** from an object, or **separating out** positive and negative charges within an object. **Charging up** an object **does** **not** mean **creating new charges**.

This can be accomplish in **3 different ways**:

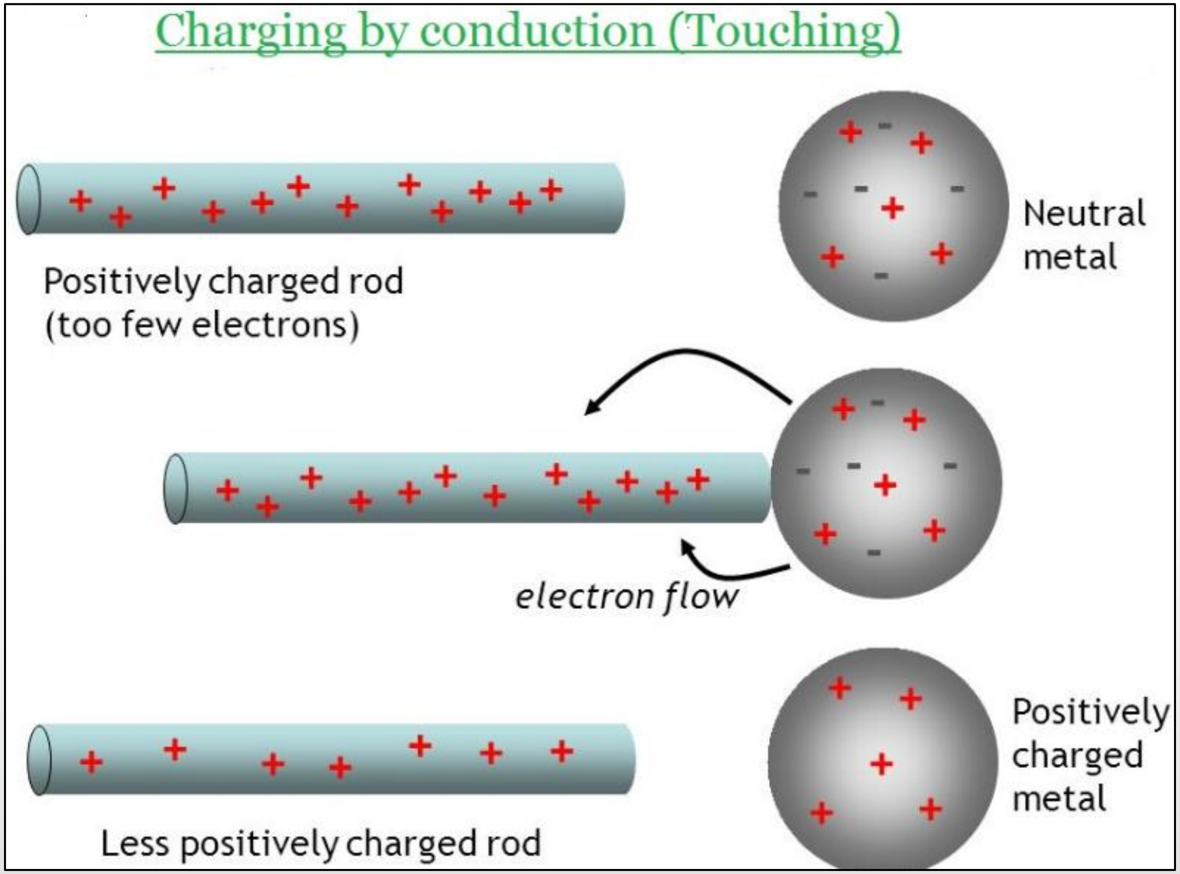
1- Charging up by Friction: Rubbing two materials together can **rub electrons off** of one and **onto** the other.

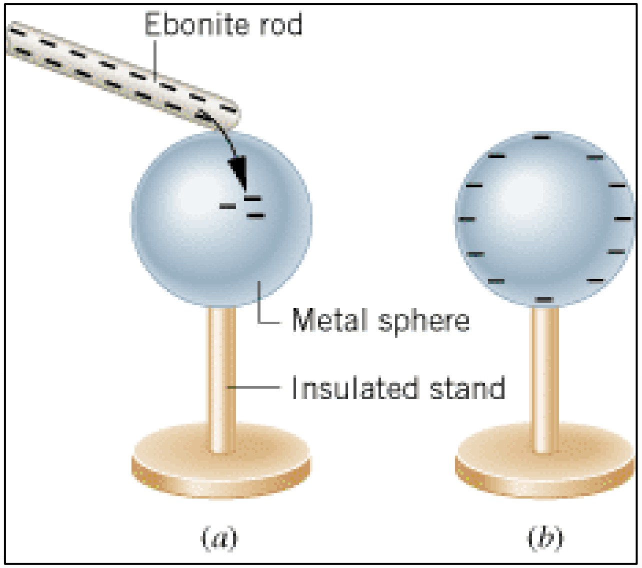


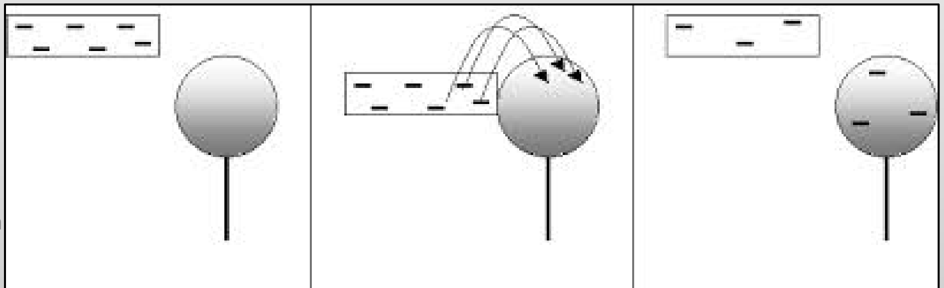
If you use a cloth to rub a plastic ruler, **electrons move from the cloth to the ruler.** The ruler gains electrons and the cloth loses electrons.

2- Charging up by Conduction: Touching an object to a charged object could lead to a flow of charge between them.

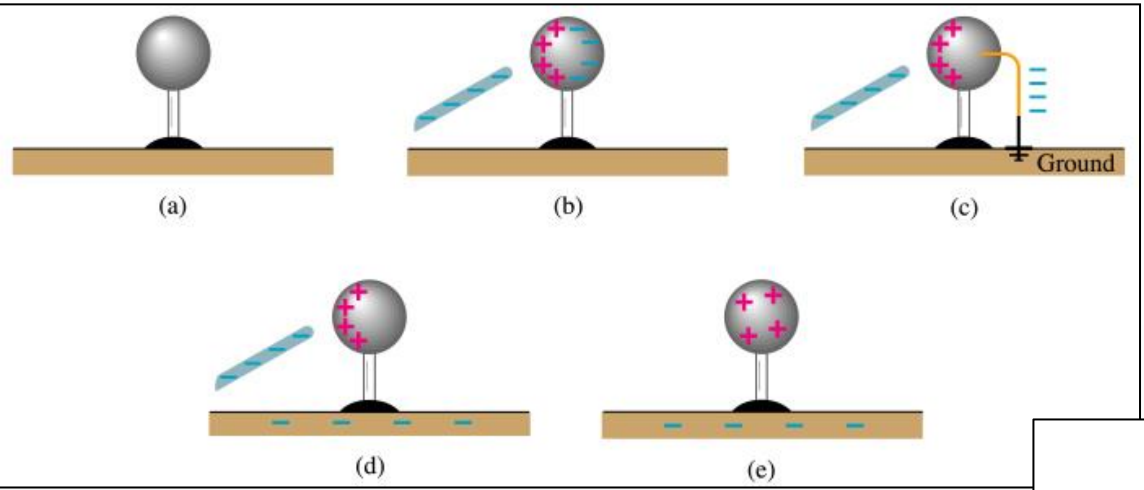
very hard rubber.

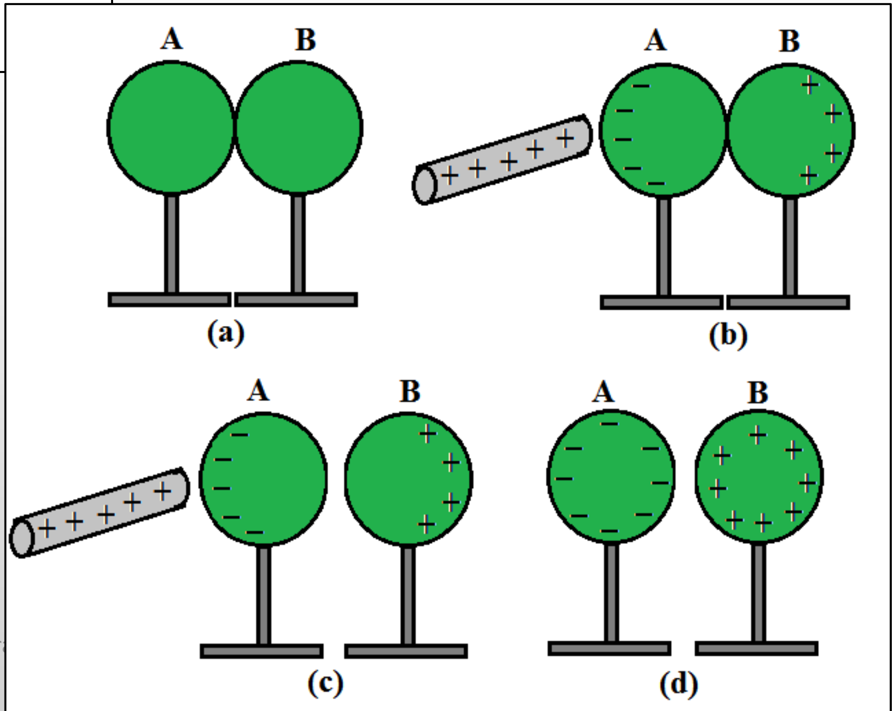






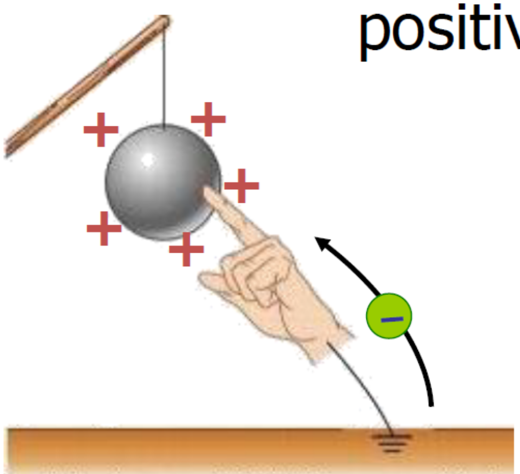
3- Charging up by Induction: If a charged object is brought near (but not touching) a second object, the charged object could attract or repel electrons (depending on its charge) in the second object. This yields a separation charge in the second object, an induced charge separation.





How does grounding occur?

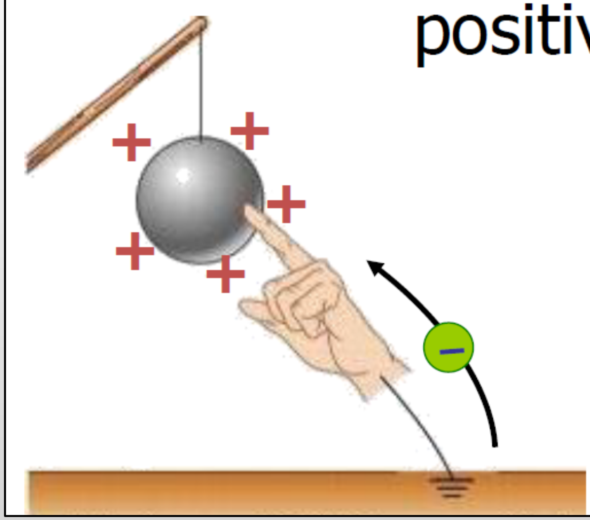
When we touch a metal ball of positive charge...



Electrons flow from the earth to the metal ball to neutralize the metal ball.

Metal ball becomes neutral.

When we touch a metal ball of positive charge...

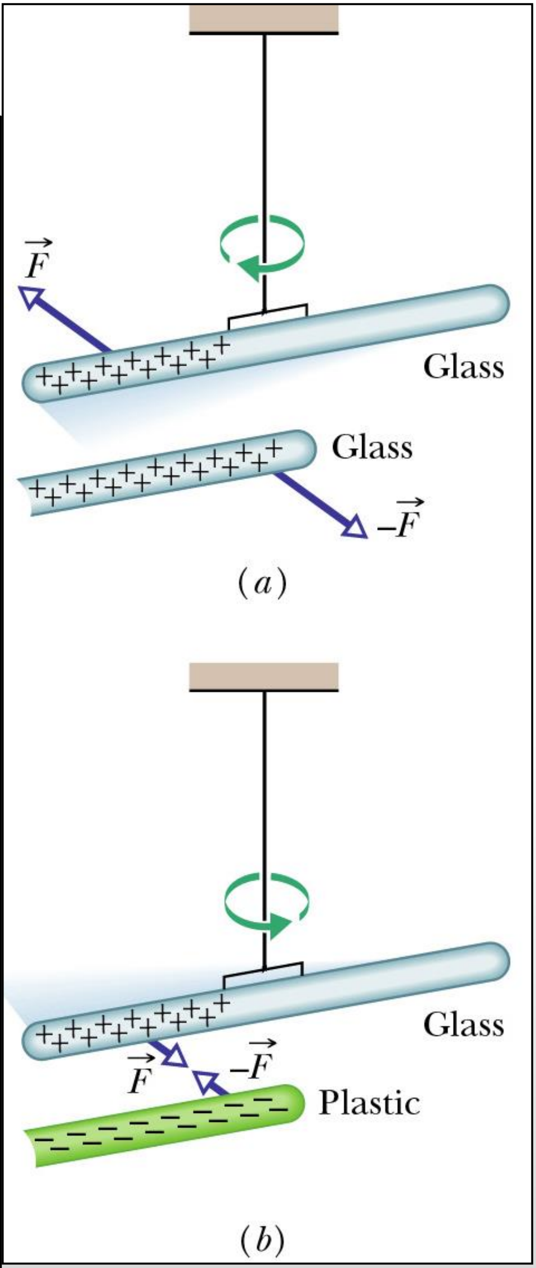


Electrons flow from the earth to the metal ball to neutralize the metal ball.

Metal ball becomes neutral.

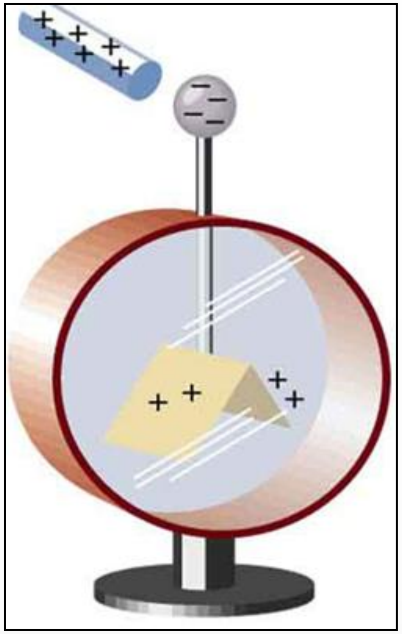
Glass Rod/Plastic Rod

- A glass rod rubbed with silk gets a positive charge.
- A plastic rod rubbed with fur gets a negative charge.
- Suspend a charged glass rod from a thread, and another charged glass rod repels it.
- A charged plastic rod, however, attracts it.
- This mysterious force is called the electric force.
- Many similar experiments of all kinds led Benjamin Franklin (around 1750) to the conclusion that there are two types of charge, which he called *positive* and *negative*.
- He also discovered that charge was not created by rubbing, but rather the charge is transferred from the rubbing material to the rubbed object, or vice versa.

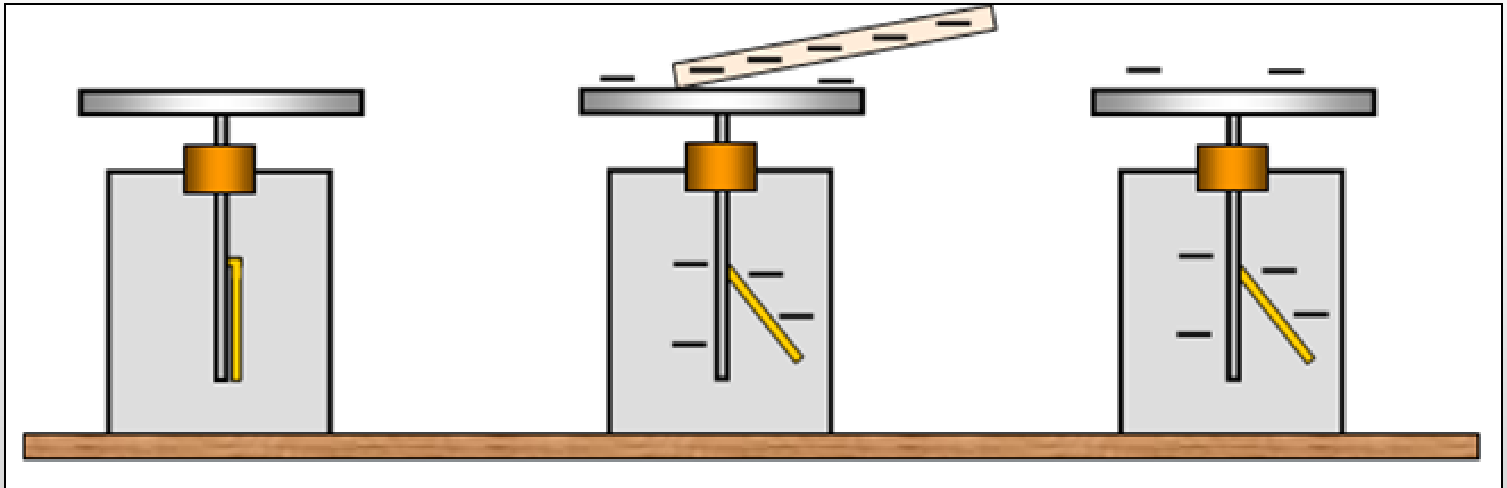


Electroscope

Charging by Induction

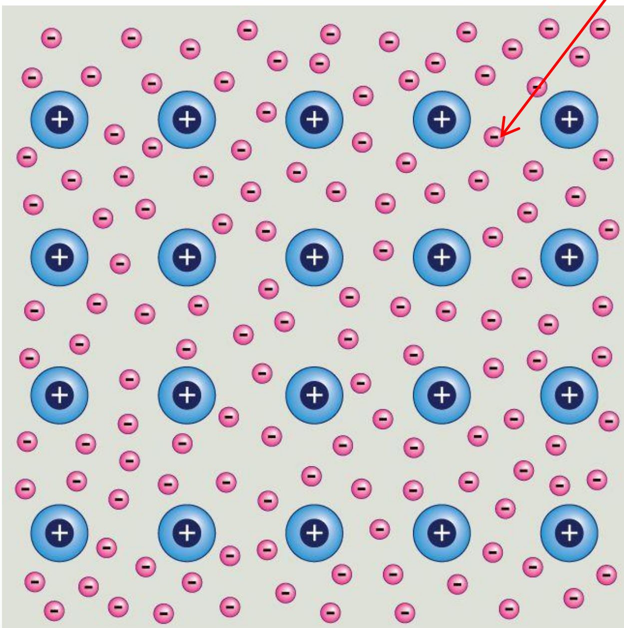


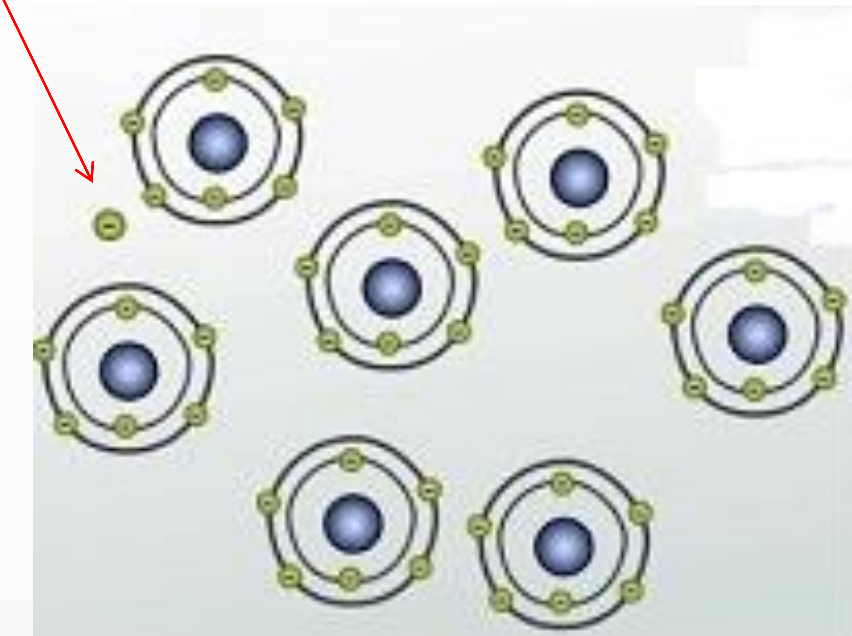
Electroscope is used to detect the presence and magnitude of electric charge on a body. It was the first electrical measuring instrument. The first **electroscope**, a pivoted needle called the versorium, was invented by British physician William Gilbert around 1600.



Charging by contact

Conductors **Free Electrons** **Insulator**





Has a sea of free electrons which can move almost freely and transfer electrical energy efficiently.

Has very few, if any, free electrons and does not transfer electrical energy well, if at all

Insulators: Do not conduct charges: glass, rubber, paper, plastic

Semi-conductors: Intermediate conduction properties -- silicon, germanium.

Conductors: Charges can move freely. Most metals.

Electric charge - **Forces Between Charges**

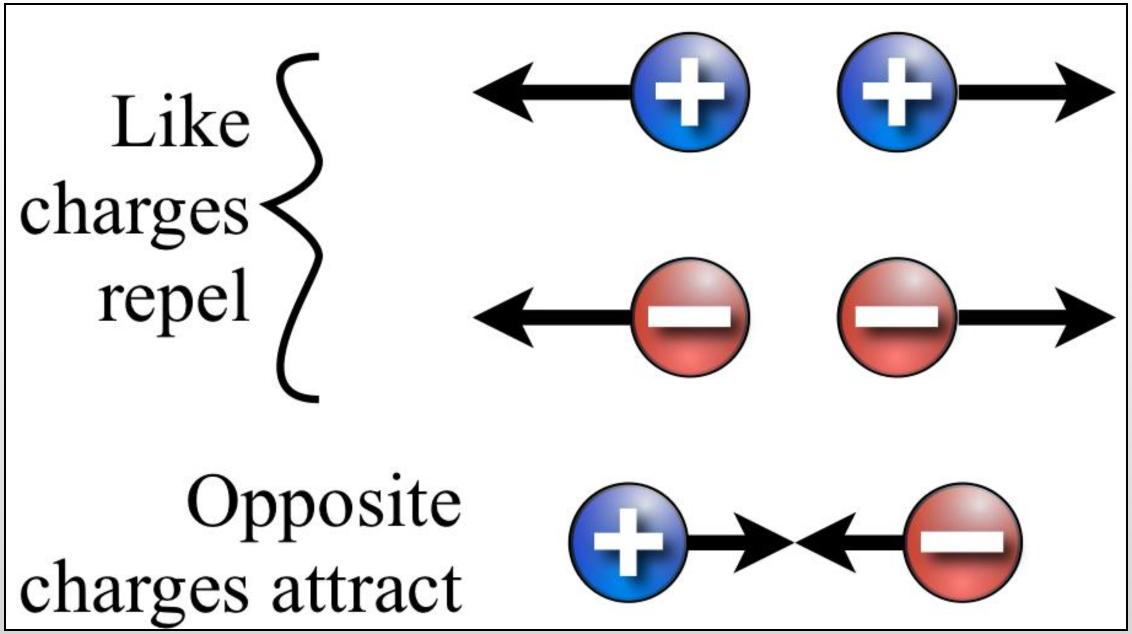
There are two kinds of electric charges, charges may be added to each other algebraically just like real (positive and negative) numbers.

$$Q = \sum_i q_i = e + 2e - 3e + 4e = 4e$$

$$e = elementary\ charge = 1.6 \times 10^{-19}\ Coloumb$$

The law of electric charges may be stated as follows:

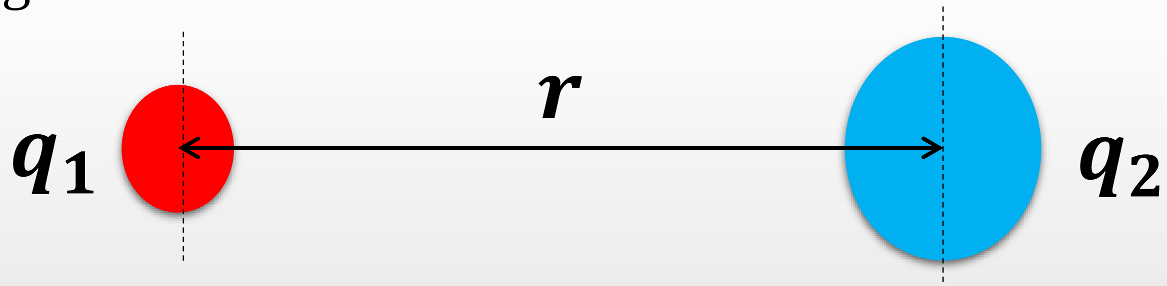
Like charges repel each other; unlike charges attract each other.



Coulomb's Law: Gives the electric force between two point charges

Coulomb's experiments showed that the electric force between two stationary charged particles:

1. is inversely proportional to the square of the separation *r* between the particles and directed along the line joining them
2. is proportional to the product of the charges *q*1 and *q*2 on the two particles;
3. is attractive if the charges are of opposite sign and repulsive if the charges have the same sign.



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

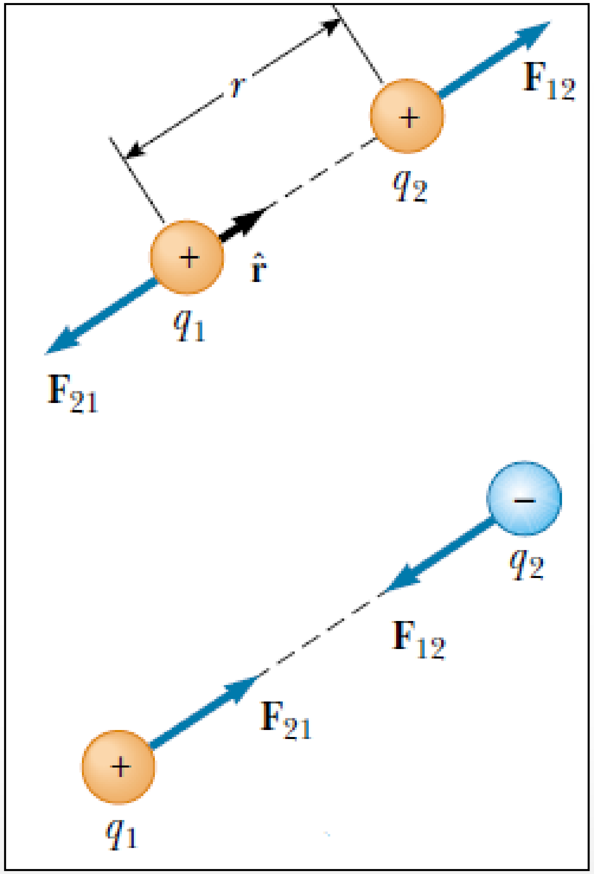
$$K = \frac{1}{4\pi\epsilon_0} = 8.9875 \times 10^9\, N.m^2/C^2$$

Permitivity of free space $\epsilon_0 = 8.8542 \times 10^{-12}\, C^2/\,N.m^2$

Vector form of Coulomb's Law

When dealing with Coulomb's law, you must remember that force is a vector quantity (not scalar) and must be treated accordingly. Thus, the law expressed in vector form for the electric force exerted by a charge q_1 on a second charge q_2 , written F_{12}, is

$$F_{12} = K_e \frac{q_1 q_2}{r^2} \hat{r}$$



Where $\hat{r}$ is the unit vector directed from q_1 to q_2 as shown in the figure.

$$F_{12} = -F_{21}$$

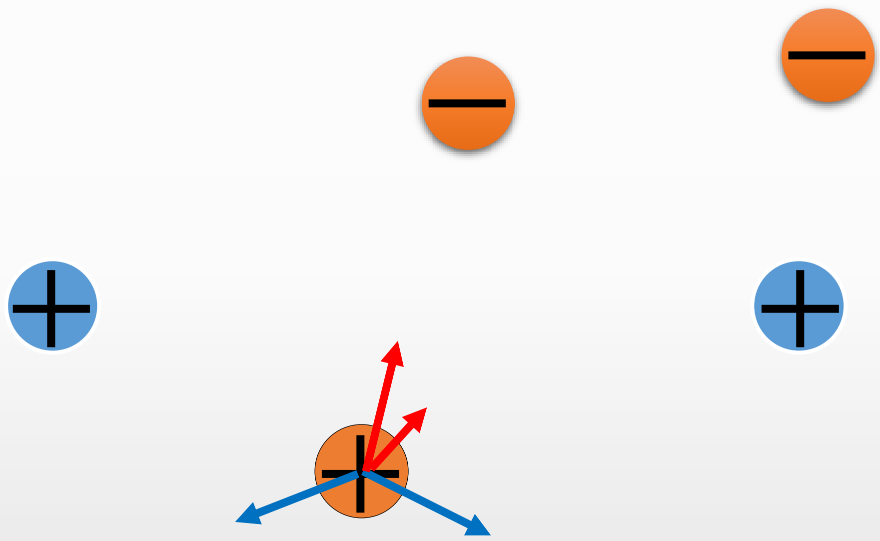
According to the Newton's third law.

When more than two charges are present, the force between any pair of them is given by Coulomb's law. Therefore, the resultant force on any one of them equals the vector sum of the forces exerted by the various individual charges. For example, if four charges are present, then the resultant force exerted by particles 2, 3, and 4 on particle 1 is

$$F_1 = F_{21} + F_{31} + F_{41}$$

Case of Multiple Charges

- You can determine the force on a particular charge by adding up all of the forces from each charge.

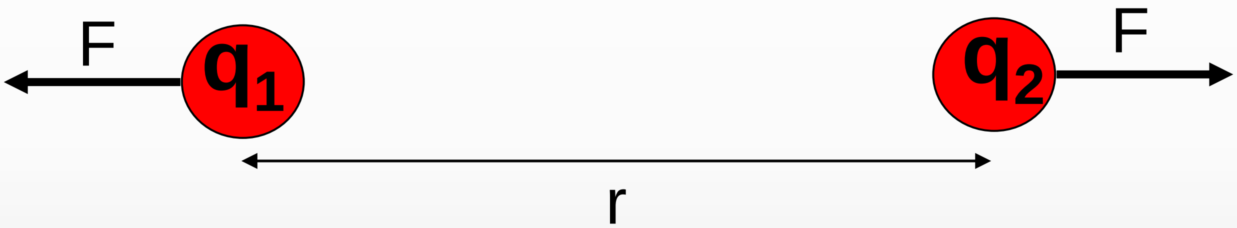


Forces on one charge due to a number of other charges

Example

Two charges are separated by a distance r and have a force F on each other.

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



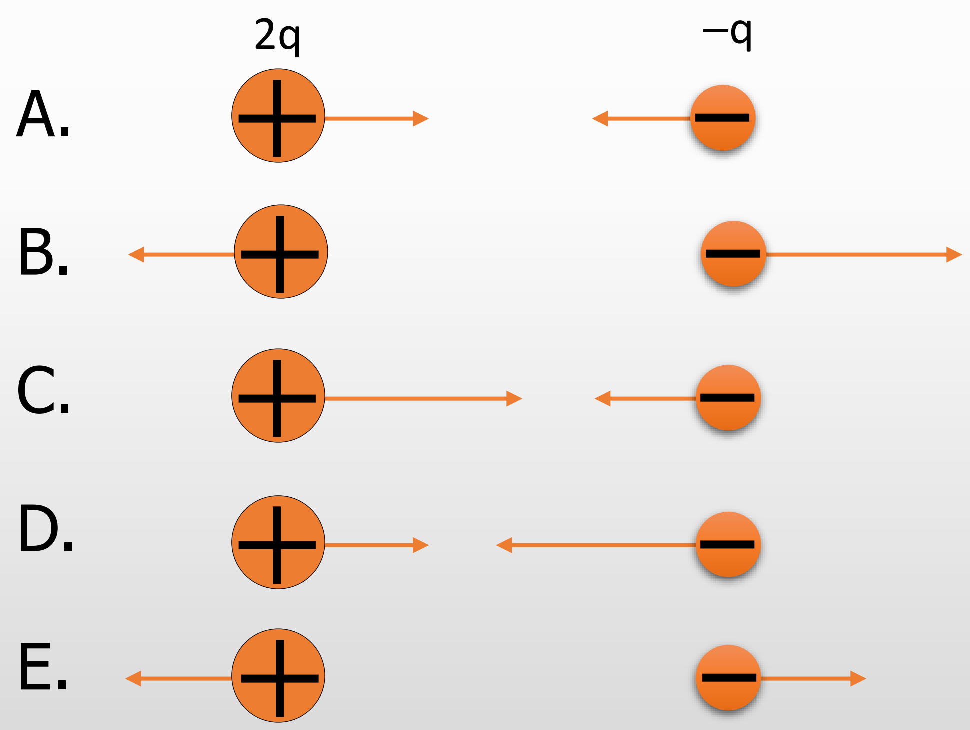
If r is doubled then F is : ¼ of F

If q_1 is doubled then F is : 2F

If q_1 and q_2 are doubled and r is halved then F is : 16F

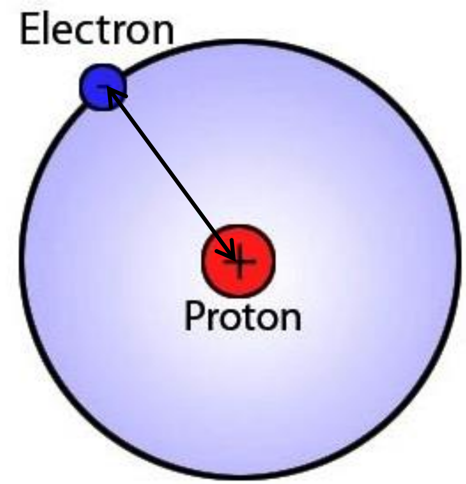
Example
Correct Forces

Two small spheres are charged with equal and opposite charges, and are placed 30 cm apart. Then the charge on sphere 1 is doubled. Which diagram could be considered to show the correct forces?



Example
Hydrogen Atom

$r = 5.3 \times 10^{-11}\text{m}$



EXAMPLE 23.1 The Hydrogen Atom

The electron and proton of a hydrogen atom are separated (on the average) by a distance of approximately 5.3×10^{-11} m. Find the magnitudes of the electric force and the gravitational force between the two particles.

Solution From Coulomb's law, we find that the attractive electric force has the magnitude

$$F_e = k_e \frac{|e|^2}{r^2} = \left(8.99 \times 10^9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right) \frac{(1.60 \times 10^{-19}\ \text{C})^2}{(5.3 \times 10^{-11}\ \text{m})^2}$$

$$= \boxed{8.2 \times 10^{-8}\ \text{N}}$$

Using Newton's law of gravitation and Table 23.1 for the particle masses, we find that the gravitational force has the magnitude

$$F_g = G$$

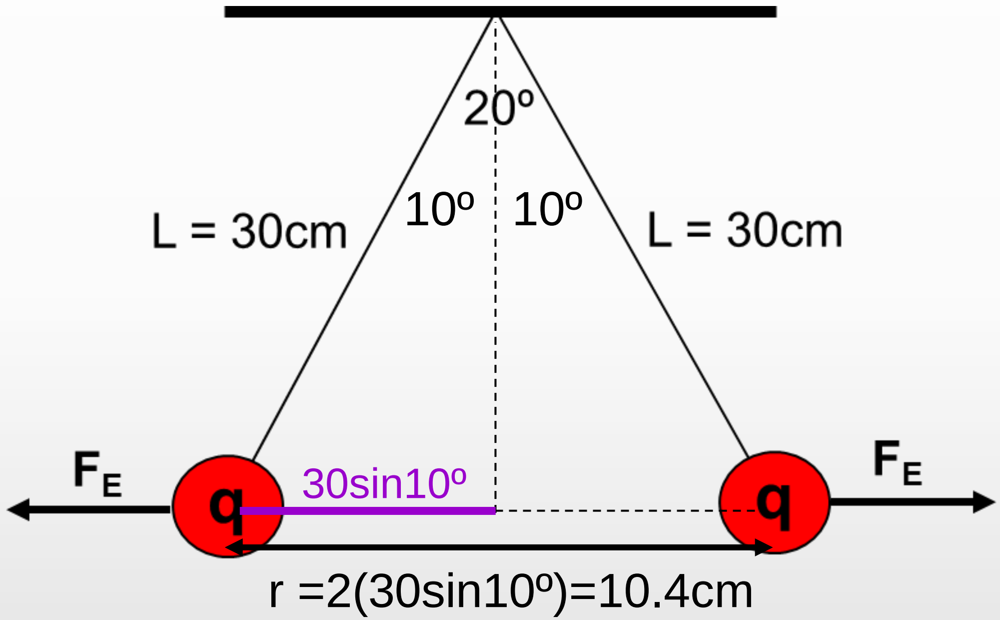
$$= \left(6.7 \times 10^{-11} \frac{\text{N}\cdot\text{m}^2}{\text{kg}^2}\right)$$

$$= \times \frac{(9.11 \times 10^{-31}\ \text{kg})(1.67 \times 10^{-27}\ \text{kg})}{(5.3 \times 10^{-11}\ \text{m})^2}$$

$$= \boxed{3.6 \times 10^{-47}\ \text{N}}$$

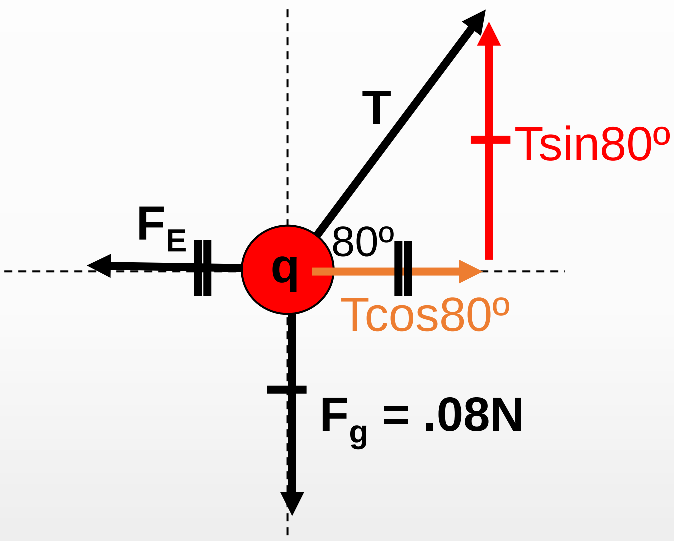
The ratio $F_e/F_g \approx 2 \times 10^{39}$. Thus, the gravitational force between charged atomic particles is negligible when compared with the electric force. Note the similarity of form of Newton's law of gravitation and Coulomb's law of electric forces. Other than magnitude, what is a fundamental difference between the two forces?

Two 8 gram, equally charged balls are suspended on earth as shown in the diagram below. Find the charge on each ball.



$$F_E = k\frac{q_1 q_2}{r^2} = k\frac{q^2}{r^2}$$

Draw a force diagram for one charge and treat as an equilibrium problem.



$$T \sin 80^\circ = .08$$

$$T = \frac{.08}{\sin 80^\circ} \approx .081N$$

$$F_E = T\cos 80^\circ$$

$$k\frac{q^2}{.104^2} = (.081)\cos 80^\circ$$

$$q^2 = \frac{.014}{k}(.104)^2$$

$$q = 1.3\times 10^{-7}\,C$$

$$\epsilon_0 = 8.8542\times 10^{-12}\ C^2/\ N.m^2$$

$$K = \frac{1}{4\pi\epsilon_0} = 8.9875\ \times 10^9\ N.m^2/C^2$$

Two small charged objects attract each other with a force F when separated by a distance d. If the charge on each object is reduced to one-fourth of its original value and the distance between them is reduced to $d/2$ the force becomes:

A) $F/16$
B) $F/8$
C) $F/4$
D) $F/2$
E) F

A small object has charge Q. Charge q is removed from it and placed on a second small object. The two objects are placed 1 m apart. For the force that each object exerts on the other to be a maximum. q should be:

A) $2Q$
B) Q
C) $Q/2$
D) $Q/4$
E) 0

How Lightning Forms

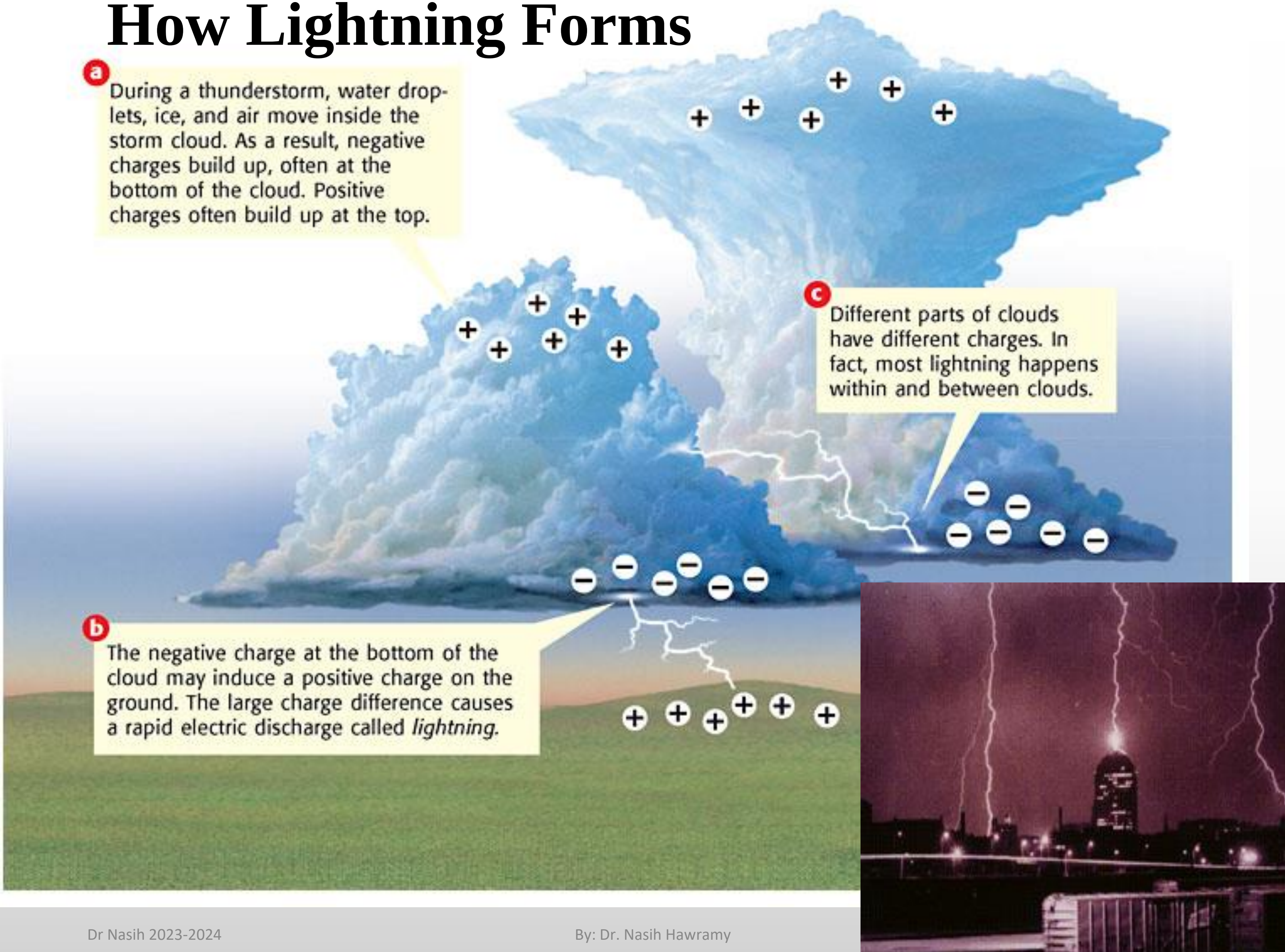
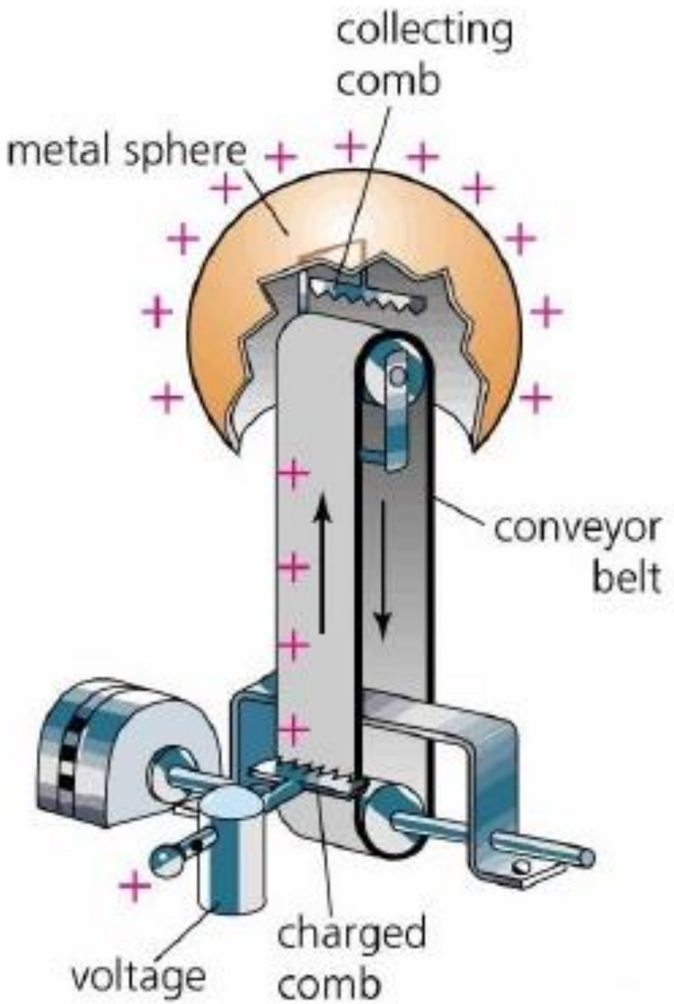


TABLE 23.1 Charge and Mass of the Electron, Proton, and Neutron

Particle	Charge (C)	Mass (kg)
Electron (e)	$-1.602\,191\,7 \times 10^{-19}$	$9.109\,5 \times 10^{-31}$
Proton (p)	$+1.602\,191\,7 \times 10^{-19}$	$1.672\,61 \times 10^{-27}$
Neutron (n)	0	$1.674\,92 \times 10^{-27}$

- **Electron**: Considered a point object with radius less than 10^{-18} meters with electric charge e= -1.6 x 10^{-19} Coulombs (SI units) and mass m_e= 9.11 x 10^{-31} kg
- **Proton**: It has a finite size with charge +e, mass m_p= 1.67 x 10^{-27} kg and with radius
  - 0.805 +/-0.011 x 10^{-15} m scattering experiment
  - 0.890 +/-0.014 x 10^{-15} m Lamb shift experiment
- **Neutron**: Similar size as proton, but with total charge = 0 and mass m_n=1.67492×10-^{27} kg
  - Positive and negative charges exists inside the neutron
- **Pions:** Smaller than proton. Three types: + e, - e, 0 charge and radius
  - 0.66 +/- 0.01 x 10^{-15} m
- **Quarks**: Point objects. Confined to the proton and neutron,
  - Not free
  - Proton (uud) charge = 2/3e + 2/3e -1/3e = +e
  - Neutron (udd) charge = 2/3e -1/3e -1/3e = 0
  - An isolated quark has never been found

VAN DE GRAAFF GENERATOR:



A Van de Graaff generator is an electrostatic machine which uses a moving belt to accumulate very high electrostatically stable voltages on a hollow metal globe. The potential differences achieved in modern Van de Graaff generators can reach 5 megavolts.

Wimshurst Machine

The Englishman, James Wimshurst (1832-1903), spent most of his professional career working with the shipping industry as a surveyor and evaluator of ships, serving as the consulting engineer for the British Board of Trade.. At the same time he had a parallel career in science. We know him for his work with electrostatic generators in the early 1880s, when he improved Voss' electrostatic generator.

In Wimshurst design, the disks contra-rotate. The metal foil sectors on the disks induce charges on each other, which are picked off with metal brushes and stored in Leiden jars.