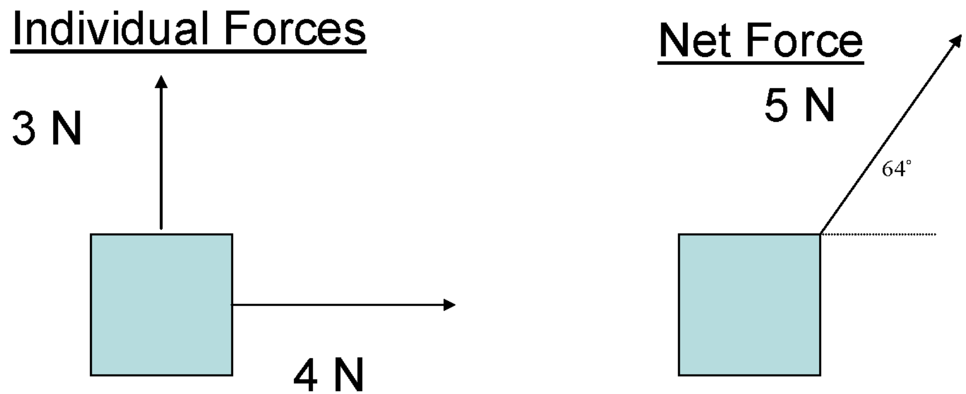
A REVIEW

A *force* is a push or a pull.

The ***net force*** $\sum \vec{F}$ is the vector sum of all of the forces acting on an object.



[Review the component method for adding vectors]

$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$$

Consequences from the N II L

- Net force = 0 => Acceleration = 0
- Net force ≠ 0 => Acceleration ≠ 0
- Acceleration = 0 => Net force = 0
- Acceleration ≠ 0 => Net force ≠ 0

What force was acting between the rods making them moving?

1 Force of gravity

2 Elastic force

3 Normal force

4 Frictional force

5 None of the above

Matter is made of …

Objects

Objects are made of …

Substances

Substances are made of …

Molecules

Molecules are made of …

Atoms

Atoms are made of …

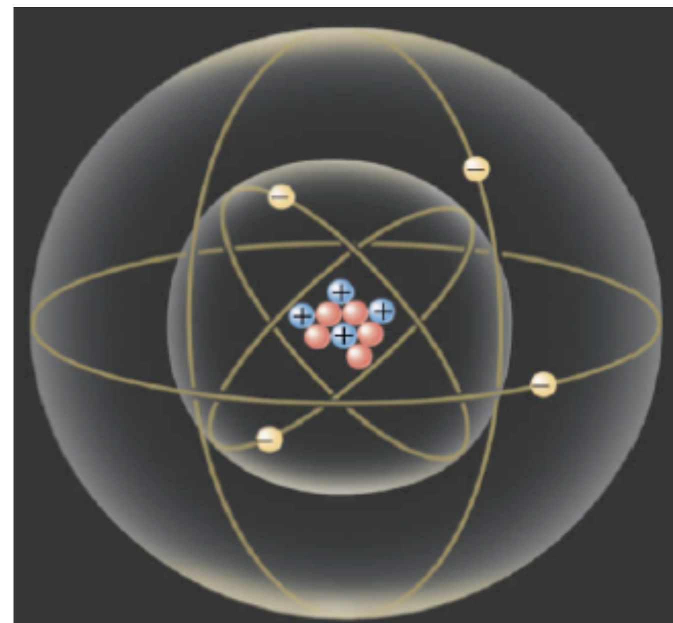
Atoms are made of …

1. Protons and neutrons

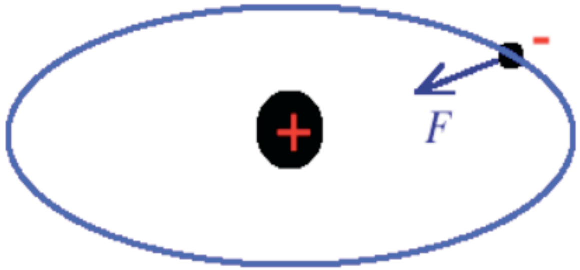
2. Electrons and nucleons

3. Electrons and a nucleus

4. None of the above



A Hydrogen Atom



An electron carries a negative charge $q_e = -1.6 * 10^{-19} C$.

A proton carries a positive charge $e = q_p = 1.6 * 10^{-19} C$ (which is also called *an elementary charge*).

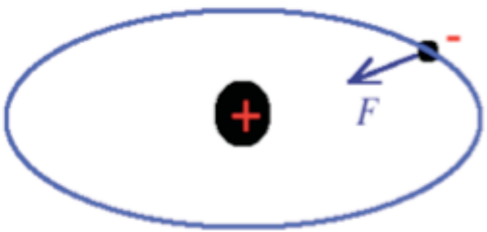
A positive charge and a negative charge always attract each other!

Some elementary particles.

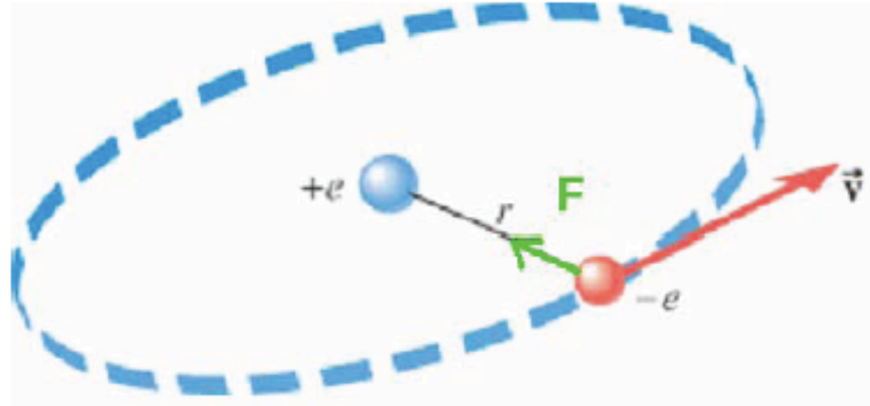
Positive $(1.6 * 10^{-19} C)$	**Negative** $(-1.6 * 10^{-19} C)$
p proton	**β^- electron**
β^+ positron	

In the Bohr model of the hydrogen atom, an electron circles a proton. Let's say the orbit has the radius of $5.29 x 10^{-11}$m.. Find the electron's speed (The electron mass is 9.1×10^{-31} kg).

The speed is 2.2 x 10^{6} m/s => 1. agree 2. disagree



$$q_p = 1.6 * 10^{-19} C$$
$$q_e = -1.6 * 10^{-19} C$$
$$|F_{el}| = k \frac{|q_1 \cdot q_2|}{r^2}$$
$$k = 8.99 \times 10^9 \ \mathrm{N \cdot m^2}$$



$$F = k\frac{|q_1||q_2|}{r^2} = \frac{\left(8.99\times10^{9}\,\mathrm{N\cdot m^2/C^2}\right)\left(1.60\times10^{-19}\,\mathrm{C}\right)^2}{\left(5.29\times10^{-11}\,\mathrm{m}\right)^2} = 8.22\times10^{-8}\,\mathrm{N}$$

$$F = ma_c = mv^2/r$$

$$\Longrightarrow \quad v = \sqrt{Fr/m} = \sqrt{\frac{\left(8.22\times10^{-8}\,\mathrm{N}\right)\left(5.29\times10^{-11}\,\mathrm{m}\right)}{9.11\times10^{-31}\,\mathrm{kg}}} = 2.18\times10^{6}\,\mathrm{m/s}$$

Choose a correct ending.

When an object is neutral it means ...

1. it does not have any electrons in it

2. it does not have any protons in it

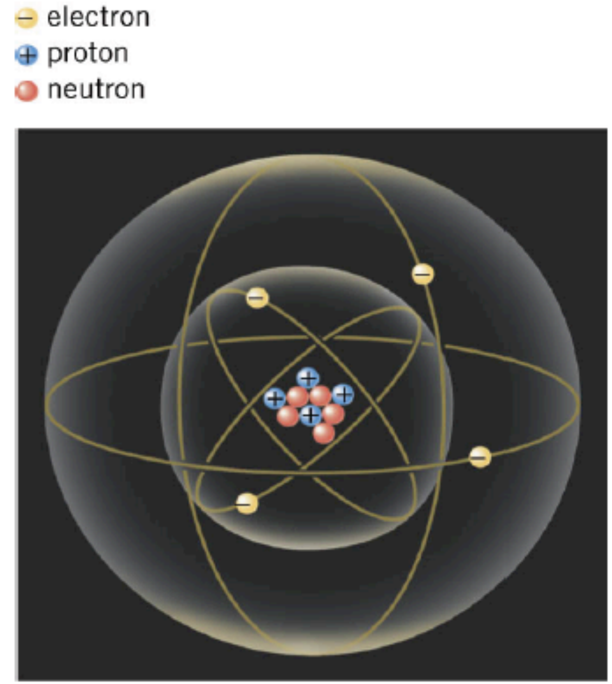
3. it has more protons than electrons

4. it has more electrons that protons

5. it has exactly the same number of protons and electrons

With this information we can explain many experiments!

The electrical nature of matter
is inherent
in atomic structure.



$$m_p = 1.673 \times 10^{-27}\,\mathrm{kg}$$

$$m_n = 1.675 \times 10^{-27}\,\mathrm{kg}$$

$$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$$

$$e = e_p = e_+ = 1.60 \times 10^{-19}\,\mathrm{C}$$

$$e_e = e_- = -1.60 \times 10^{-19}\,\mathrm{C}$$

coulombs

$$e_n = 0\,\mathrm{C}$$

an elementary charge is the minimum portion of a charge!

$N_e = N_p$, total charge of an atom is 0!

A *neutral* <u>atom</u> has exactly the same number of electrons and protons.

$$N_e = N_p$$

A *neutral* <u>object</u> has exactly the same number of electrons and protons.

$$N_e = N_p$$

An object which has a *deficiency* of electrons ($N_e < N_p$) …

1. **is positively charged**
2. **is negatively charged**
3. **could be both, either positive or negative**
4. **is neutral**

A simple experiment

Braking off neutrality – what particles are moving?

1.Protons
2.Electrons
3.Both
4.Neither

Fan and balls experiment.

<u>Choose a correct ending.</u>

In this experiment the red ball almost does not move because …

1. it is red
2. it is much happier than the ping-pong ball
3. it is much sadder than the ping-pong ball
4. it is much heavier than the ping-pong ball
5. it is nailed to the table

Insulators (dielectrics)

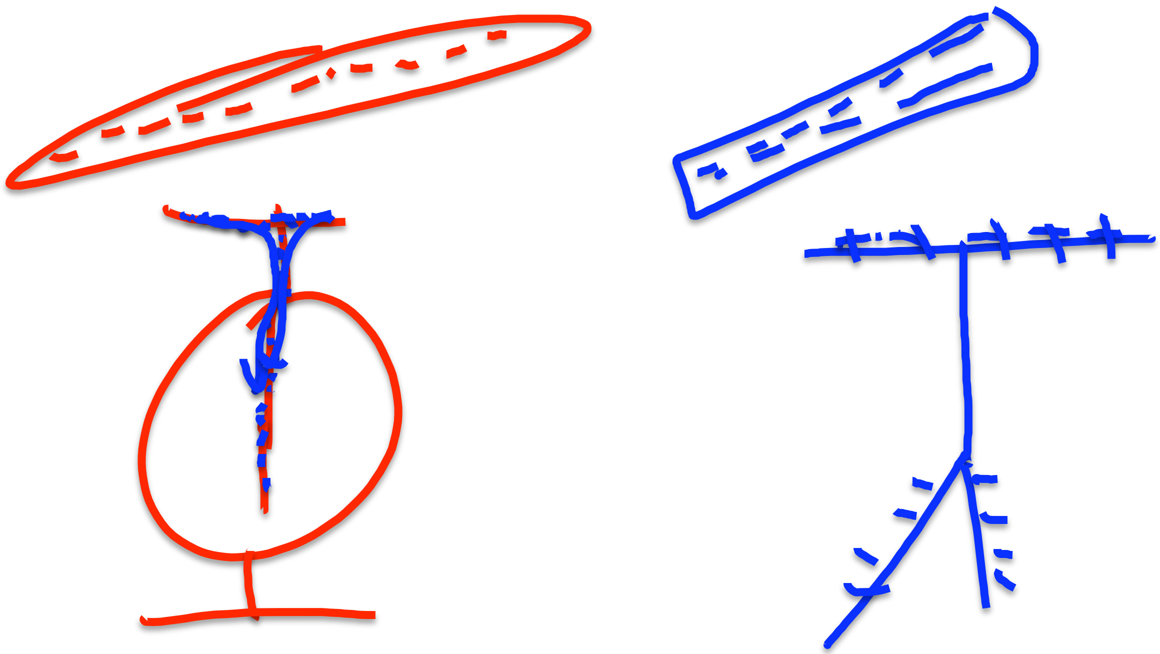
- Electrons are strongly bound to atoms
- Charges within molecule can still separate (polarize)
- Charges cannot travel through substance easily

Conductors

- Some electrons very weakly bound
- Charges travel easily through substance

Protons NEVER move. (in solids)

Electrons move easily in conductors and under strong action in insulators



A negatively charged rod is rubbed against a neutral object.

Is the object heavier or lighter than it was neutral? (In the lab you will measure $e/m_e = 1.76*10^{11}$ C/kg)

1. **Much heavier**
2. **Slightly heavier**
3. **Much lighter**
4. **Slightly lighter**
5. **The mass does not change**

A negatively charged rod is rubbed against a neutral object.

Is the object heavier or lighter than it was neutral?

2. **Slightly heavier**

When we rub an object with a negatively charged rod we transfer some electrons onto the object, which makes it slightly heavier.

To find how much heavier it becomes we need to calculate the mass of the added electrons: $\Delta m = m_e * \Delta N_e$.

Q is the charge of the rod. m_e is the mass of one electron.

ΔN_e is the number of the added electrons: $\Delta N_e = |Q|/e$

Law of conservation of electric charge

In a closed (isolated) system the number of protons N_p and electrons N_e is set and does not change, hence the total charge of a system $Q = e*N_p - e*N_e$ is a constant.

The total charge of a system can be changed by bringing it into a contact with an external object resulting in taking away from the system or bringing in the system some electrons (or protons).

An object has a + charge: $Q > 0$	An object has a – charge: $Q < 0$
$N_p > N_e$	$N_p < N_e$
The number of electrons the object is *missing* is N.	The number of *extra* electrons the object has is N.
The charge $Q = e*N$.	The charge $Q = -e*N$.

$|\Delta N_e| = |Q|/e$

For a neutral object $N_p = N_e$ and $Q = N = 0$

here $e = +1.6*10^{-19}$ C

Calculating charges $q_e = -1.6 * 10^{-19} C$

In solving a problem, you calculate the charges on three objects to be:

$Q_1 = 5 \times 10^{-15}$ C; $Q_2 = 5 \times 10^{-19}$ C; $Q_3 = 5 \times 10^{-23}$ C

Are any of these results clearly incorrect?

1. They're all wrong
2. Q_1 and Q_3 are wrong
3. Q_2 and Q_3 are wrong
4. Q_3 is wrong
5. No - all three of these answers are possible.

$$10^{-15} = \frac{1}{1000000000000000}$$

$$10^{-14} = \frac{1}{1\_\ \_\ \_\ \_\ \_\ \_\ .0000}$$

Calculating charges

$Q_3 = 5 \times 10^{-23}$ C is definitely a problem.

Charge is quantized – it comes in packets of magnitude *e*.

$$e = 1.60 \times 10^{-19} \text{ C}$$

What about $Q_1 = 5 \times 10^{-15}$ C; $Q_2 = 5 \times 10^{-19}$ C;

What is another example of something that is quantized?

Money. The smallest increment, in the American system, is the penny.

Can we transfer to the rod *exactly* 1 C?

To do that, we have to transfer *exactly* $\Delta N_e = 1/e$ electrons.

$$\Delta N_e = 1 / (1.602176487 * 10^{-19}) =$$

$$= 0.62415096471204178918412708299001678824 42*10^{19} =$$

$$= 6241509647120417891.84127082990016788 2442$$

Can we transfer 6241509647120417891.8 electrons?

We rub a PVC rod with fur. The rod getting 5×10^{11} extra electrons.

1. Calculate the actual value of the charge on the rod.

2. How many electrons did the fur loose?

3. What is the value of the total charge of the fur – rod system before and after the mechanical interaction?

Two metal spheres of the same radius are charged.

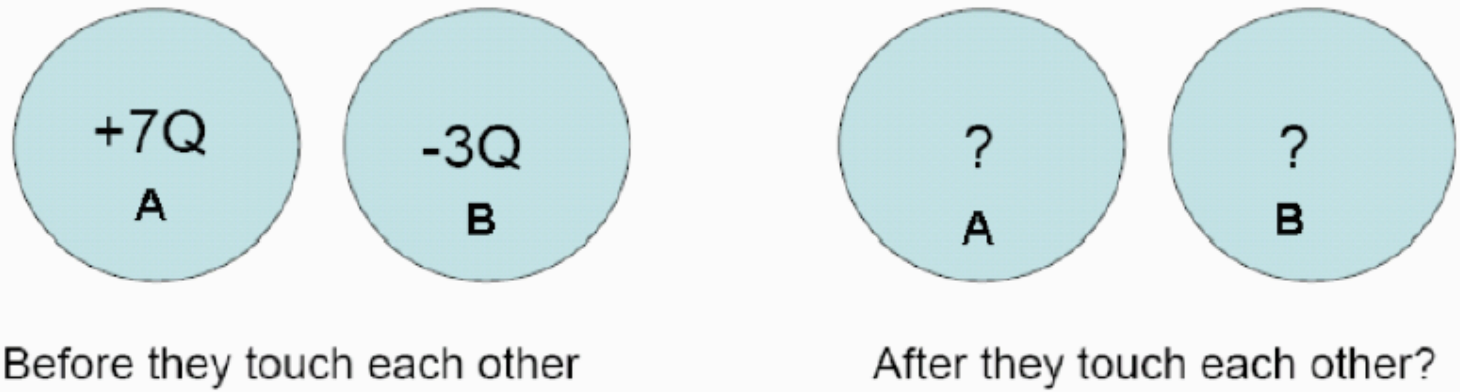
One sphere is missing $7*10^{22}$ electrons; another one has extra $3*10^{22}$ electrons.

How many electrons will be transferred from one sphere onto another one when we make them touch?

Which law do we have to use to solve this problem?

1. Newton's First law
2. Newton's Second law
3. Newton's Third law
4. Law of conservation of energy
5. Law of conservation of momentum
6. Law of conservation of charge
7. None of the above

Two spheres



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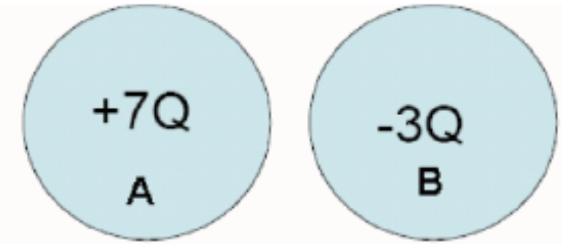
Two spheres

Let's be Q = $e*10^{22}$.



Before they touch each other

How many electrons have been transferred from one sphere onto another one during the contact?

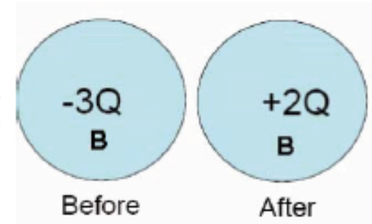
Sphere B

Before	After

1. $6*10^{23}$ **2.** $5*10^{22}$ **3.** $4*10^{21}$ **4.** $3*10^{20}$

Two spheres

Let's be Q = $e*10^{22}$.



How many electrons is sphere B having extra or missing before and after the spheres touched?

How many electrons have been transferred from one sphere onto another one during the contact?

Sphere B

Before	After
$-3Q = -3e*10^{22}$ sphere B has $3*10^{22}$ *extra* electrons	$+2Q = +2e*10^{22}$ sphere B *misses* $2*10^{22}$ electrons

At first $3*10^{22}$ electrons transferred from sphere B onto sphere A, and then $2*10^{22}$ electrons more, so totally, $5*10^{22}$ electrons transferred from sphere B onto sphere A.

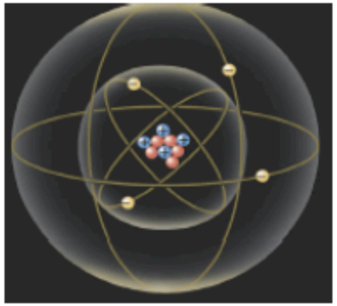
Two identical metal balls carry charges of +3 μC and -12 μC. They are 3 m apart. We brought the charges together and then placed again at the same distance. (a) Calculate the charge on each ball after they has been brought in a contact. (b) If both charges are positive (or negative), calculate the new charges on each ball.

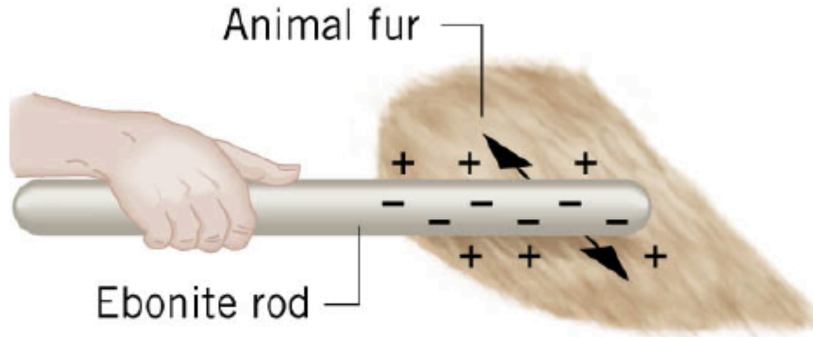
Two different metal balls carry charges of +3 μC and -12 μC. They are 3 m apart. We brought the charges together and then placed again at the same distance. We see that now the magnitude of the charge on one ball is four times of the magnitude of the charge on another ball. (a) Calculate the charge on each ball after they has been brought in a contact. (b) If both charges are positive (or negative), calculate the new charges on each ball.

What difference do you observe between the case when you take a negatively charged rod and touch with it a plate of a neutral electroscope vs. the case when you rub the rod against the plate?

How do you explain it?

Charging = breaking the balance!





LAW OF CONSERVATION OF ELECTRIC CHARGE

During any process, the net electric charge of an isolated system remains constant (is conserved).

If you have a negatively charged plastic rod, what can you do to discharge it (i.e. to make it neutral)?

Insulator vs. Conductor

We start from two neutral electroscope, we place a screwdriver (or a plastic rod) on the plates and start charging the one on the right. The arm of the one on the left …

1. does not move
2. deflects but goes back
3. deflects and stays deflected

<u>Choose one correct statement:</u>

1. Electrons attract each other because they negative

2. Protons repel each other because they negative

3. Electrons and protons repel each other because they have opposite charges

4. Electrons and protons attract each other because they have opposite charges

6. All statements are incorrect

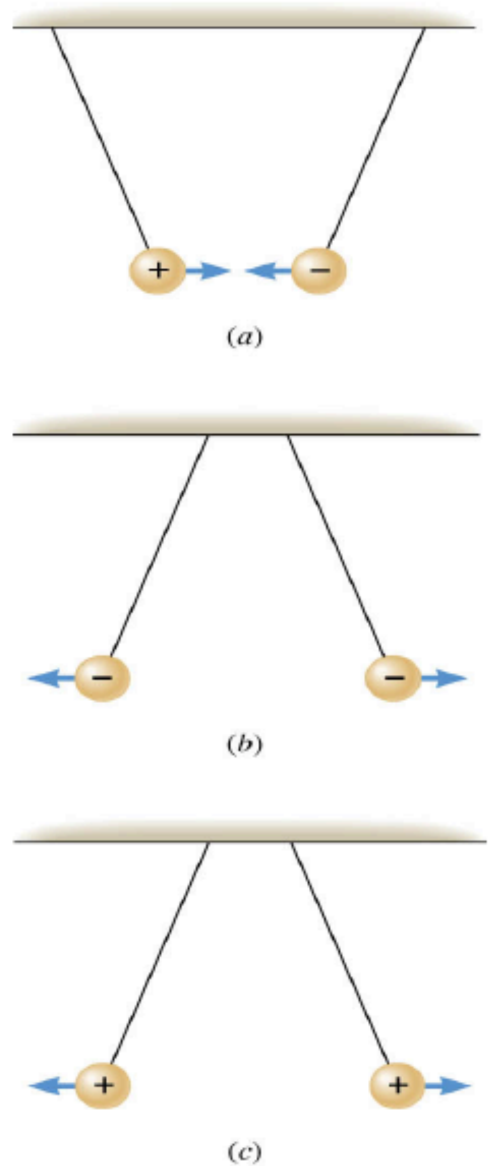
Like charges

repel

and

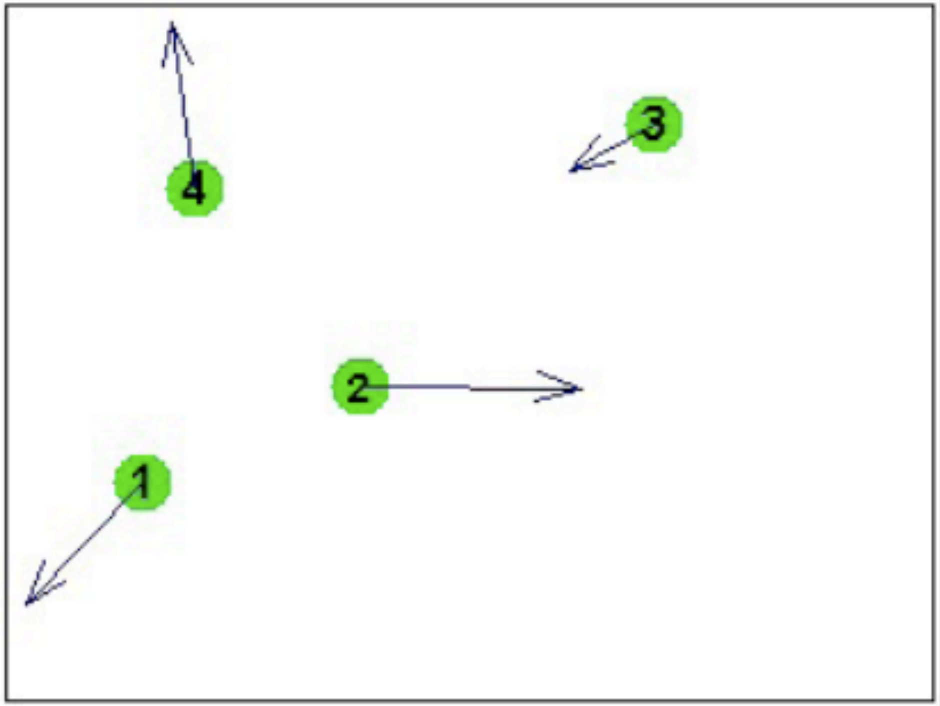
unlike charges

attract each other.

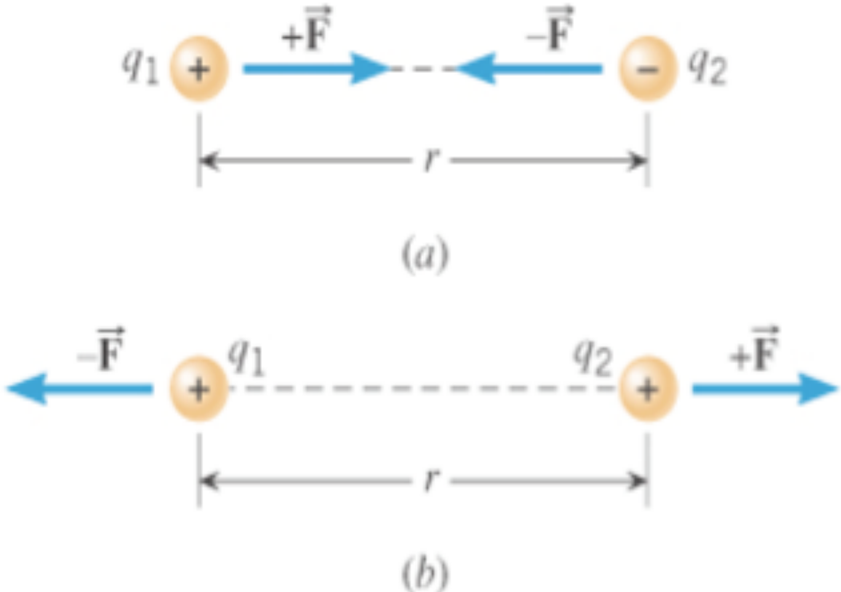


Four charged objects

How many of the objects have a positive charge?



1. One of them
2. Two of them
3. Three of them
4. Four of them
5. One or three of them, we can't tell.



Like charges repel each other, opposite charges attract each other.

Electrons in a conductor always try to become as … as possible (relative to each other).

1. Close
2. Far

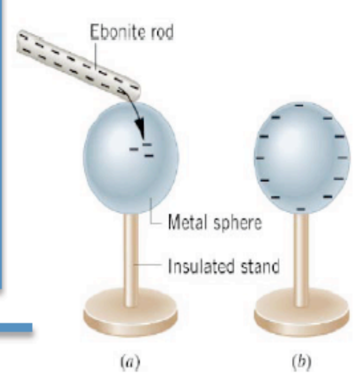
When we rub a PVC rod with fur we mechanically transfer a large number of electrons from the fur onto the rod.

Both, the rod and the fur are not neutral any more, the objects are charged!

Which object will become negative (negatively charged)?

1. **the fur**
2. **the rod**
3. **both**
4. **neither**

How can we check is it charged? (electropho -rus)



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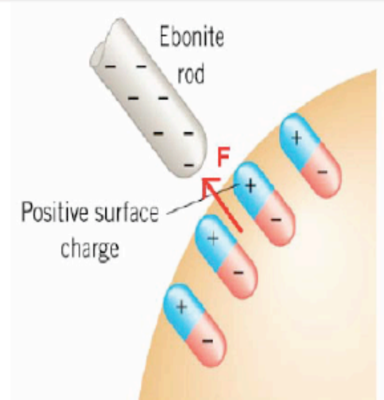
triboelectric series

MOST POSITIVE Leather
Rabbit's fur
Glass
Nylon
Wool
Silk
Paper
Cotton **NEUTRAL**
Amber
Polystyrene
Rubber balloon
Hard rubber
Saran wrap
Polyethylene
Vinyl (PVC) **MOST NEGATIVE**

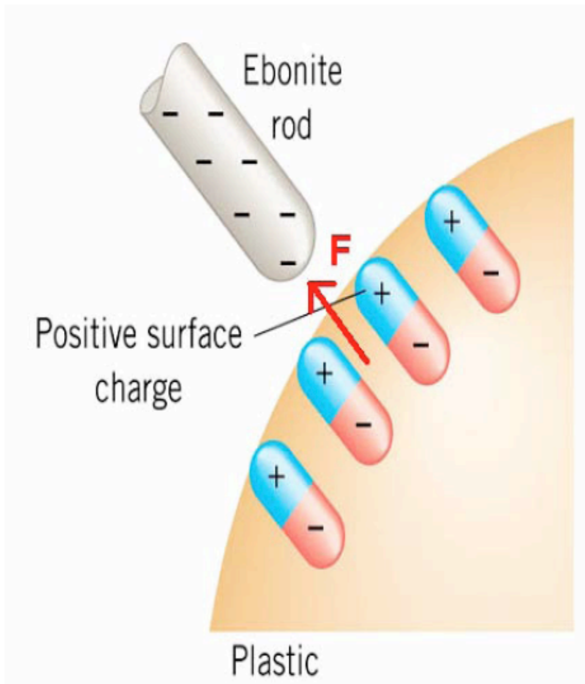
Bring vs. touch. vs. rub



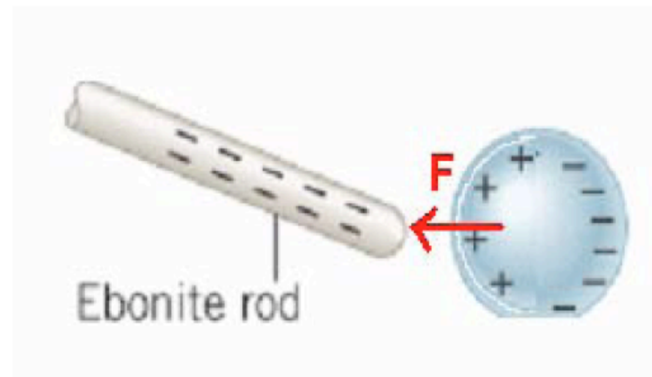
a can vs. 2x4
(what if the rod is positive?)

Attraction by induction

Insulator (2x4)



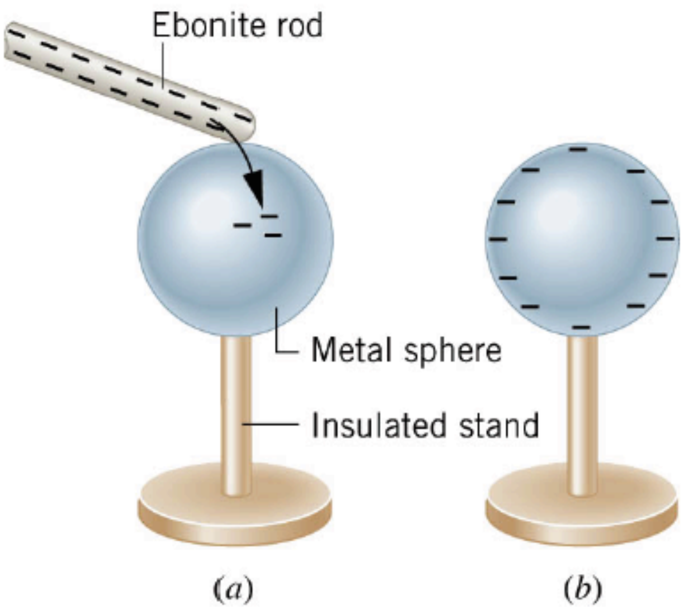
Conductor (a can)



What if the rod is positive?

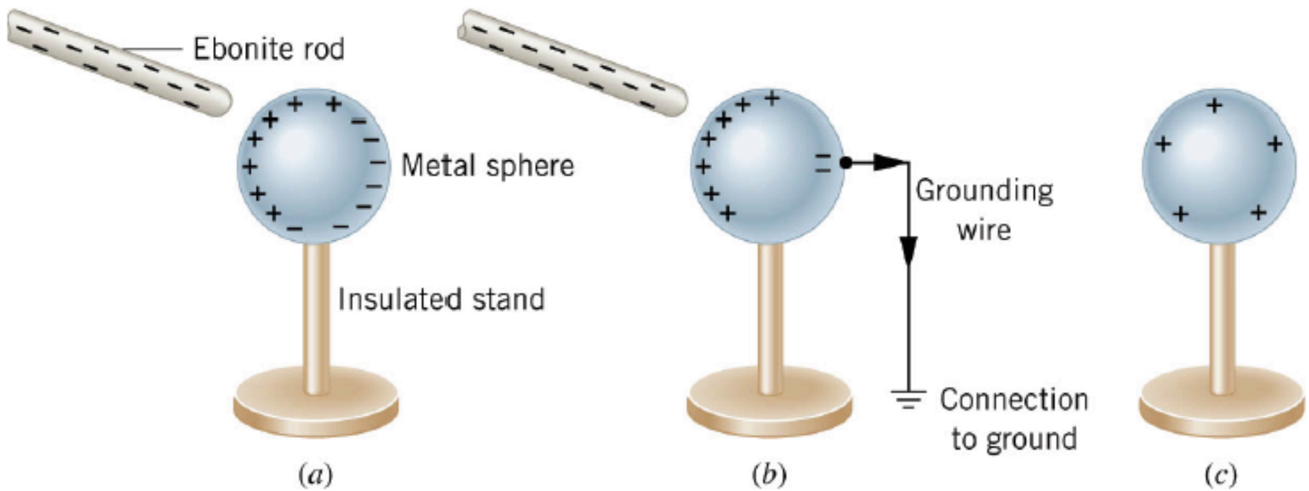
Electric force is a strong force!

Charging by contact



(What if the rod is positive?)

Charging by induction



What if the rod is positive?