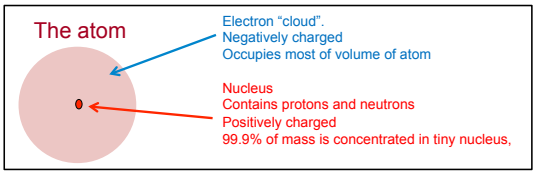
Static electricity

Why do my socks stick together after I dry them?

Lecture 19 :
Begin static electricity

Reminders:
HW 8 due Monday 5th at midnight
Reading quiz Thurs

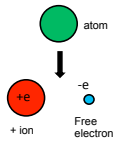
Atoms, Electrons and Ions



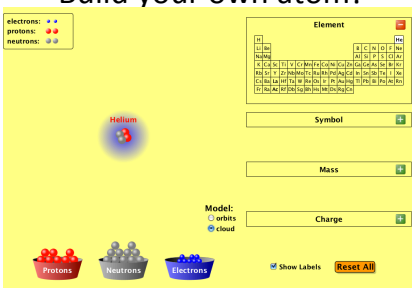
Atoms have equal number of protons and electrons, so total charge is *zero.*
⇒*They are electrically neutral*

The same is true of most ordinary objects (made of atoms.)

You can pull electrons off atoms. This leaves 2 *charged* particles :
- Unbound (free) electrons (negatively charged)
- Positively charged ions
  (ion = atom with unequal number of protons and electrons)

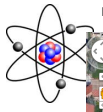


Build your own atom!

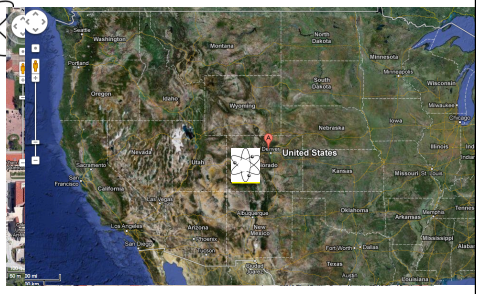


http://phet.colorado.edu/en/simulation/build-an-atom

A word about scales of the atom



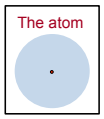
If the nucleus were the size of this room, where are the electrons?.



The nucleus is ~10,000 times smaller than the atom…

Source of electricity: Electric charges

Everything (earth, you, the table etc) made of tiny particles called atoms
Atoms are made up of 3 even tinier particles:
Electrons, neutrons and protons

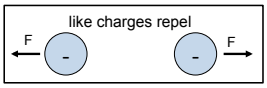


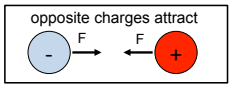
Particle	Charge	Mass
Electron	-e	9.11×10^{-31} kg
Proton	+e	1.67×10^{-27} kg
Neutron	0	1.67×10^{-27} kg

e = 1.6×10^{-19} Coulombs
Coulomb (C) is the unit of charge

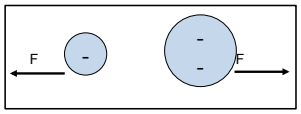
Static electricity: What happens when charges are stationary
Electricity (and electric currents): What happens when charges (usually electrons) are moving

Sorting out how charges interact





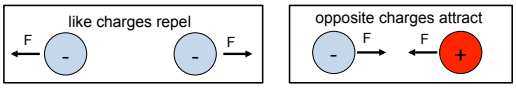
What if I have twice the charge as before?



Twice the charges – twice the force
Three times the charge, 3x the force
Ten times the charge, 10x the force

a) Half the force as before
b) Same force as before
c) Twice the force as before
d) Four times the force

Electrostatic force between charged particles



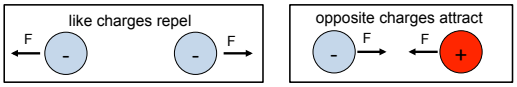
Consider 2 'point' charges, A and B. What force does charge A feel?

Observed behavior:
- Force depends on q_A and q_B : More charge, more force

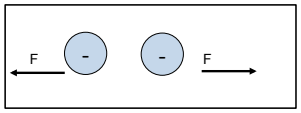
$\text{Force}_{\text{of B on A}} \sim q_A \times q_B$

note: if q's are the same sign, F is positive: pushing away
if q's are the opposite sign, F is negative: attracting together

Sorting out how charges interact



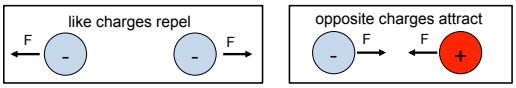
What about the distance, what if they are closer?



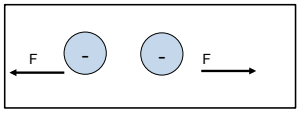
Closer means more force!

a) Less force
b) Same force as before
c) More force

Sorting out how charges interact



What about the distance, what if they are closer?



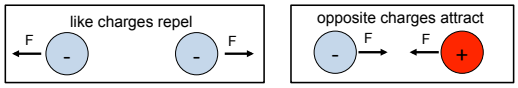
Closer means more force!

What math relationship shows this?

a) Less force
b) Same force as before
c) More force

F ~ 1/ r (is a good guess)
But it turns out to be stronger !
$F \sim 1 / r^2$

Putting this together: Electric Force



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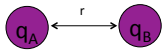


Observed behavior:
- Force depends on q_A and q_B : More charge, more force
- Force depends on distance between them (r) : less distance, more force

Coulomb's Law:
$\text{Force}_{\text{of B on A}} = \frac{k q_A q_B}{r^2}$

- Describes the force between 2 point charges
- k is Coulomb constant = 8.99 x 10^9 N m^2/C^2
- q_A and q_B are amount of charge in coulombs (C)
- r is separation in m

1 Coulomb = 6 x 10^{18} electron charges!

Electric Hockey Simulation!

$\text{Force}_{\text{of B on A}} = \frac{k q_A q_B}{r^2}$

Place charge (B) 2cm from charged puck (A). See charged puck fly away

Now place charge (B) 1 cm away from charged puck (A).
Compared to previous situation force on A will be:

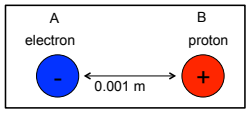
a. half as large, b. same size, c. twice as large, d. four times larger
e. something else.

d. four times larger since force depends on $1/r^2$
⇒ distance smaller, force larger

Place charge (B) 1cm away from charged puck (A) as in previous Q.
Add a second charge to B, right on top of first.
Compared to previous question, force on A is:

a. ½, b. same, c. x 2, d. x 4, e. something else.

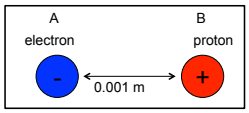
c. x 2 because force on A goes like (charge of A x charge of B),
… in this Q we doubled the charge on B



What is force between them?
Calculate and write down answer.

$\text{Force}_{\text{of B on A}} = \frac{k q_A q_B}{r^2}$

k is Coulomb constant = 8.99 x 10^9 N m^2/C^2
e = 1.6 x 10^{-19}C



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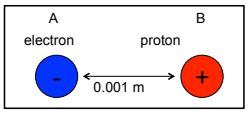
Proton and electron have charges of same magnitude (e) , opposite sign

$\Rightarrow q_A = -1.6 \times 10^{-19}$ C
$q_B = +1.6 \times 10^{-19}$ C

$$Force = \frac{(8.99 \times 10^9\ N\ m^2/C^2)\ (-1.6 \times 10^{-19}\ C)\ (1.6 \times 10^{-19}\ C)}{(1 \times 10^{-3}\ m)^2}$$

$$= \frac{-2.3 \times 10^{-28}\ N\ m^2}{1 \times 10^{-6}\ m^2} = -2.3 \times 10^{-22}\ N$$



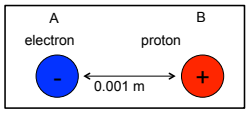
What is force between them?
Calculate and write down answer.

$Force_{of\ B\ on\ A} = \frac{kq_Aq_B}{r^2}$

Force between particles = -2.3×10^{-22} N

What does the minus sign mean?

a) Force on electron points to left
b) Force on electron points to right



What is force between them?
Calculate and write down answer.

$Force_{of\ B\ on\ A} = \frac{kq_Aq_B}{r^2}$

so Force = -2.3×10^{-22} N

What does the minus sign mean?

b) Force on electron points to right

Remember force is a vector and so requires both a magnitude and direction
⇒ Plugging numbers into Coulomb's Law give the magnitude of the force
⇒ What about the direction?

The force between 2 point charges always acts 'along the line of centers'
- If Coulomb's law gives a positive number, the charges repel
- If Coulomb's law gives a negative number the charges attract

Alternatively: Use Coulomb's law to find the magnitude of the force
Look at diagram to find direction

Summary of electrical materials:

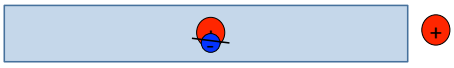
In a conductor (think: metal), free electrons can move around electrons are **not attached** to single atoms

Summary of electrical materials:

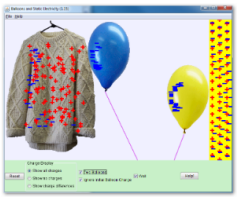
In a conductor (think: metal), free electrons can move around

Summary of electrical materials:

In an insulator, electrons remain bound to atoms



Balloon Sim



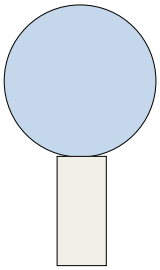
http://phet.colorado.edu/en/simulation/balloons

Static Electricity Experiments

Think like an electron!!

Here is the van de Graaff machine. Its purpose is to put a lot of negative charge on the *conducting* sphere. Where does all the charge go?

a) To the middle of the sphere
b) All around the surface of the sphere
c) To the top of the sphere
d) To the bottom of the sphere
e) Somewhere else



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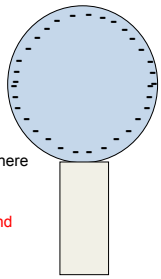
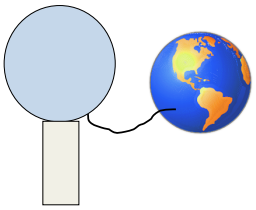


X-section of sphere

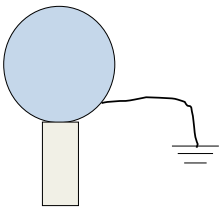
Negative charges repel, and are free to move around in conducting sphere.
They will get as far apart as possible.

What is electrical ground?



- A grounded object is connected by a wire to the earth
- The earth is like a big reservoir for supplying or receiving excess + and – charges
- So big that it can gain or lose a few charges and always remain essentially neutral
- Wire provides an easy path for charges to/from the earth
- Grounded object is always at zero volts

What is electrical ground?



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Pom-pom demo

Attach Pom-pom to top of VdG and turn on.
What will happen?

a) Nothing
b) Sparks will fly from pom-pom
c) Nasty smell of burning pom-pom will develop
d) Pom-pom strands will stand on end and repel each other

Pom-pom demo

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d) Pom-pom strands will stand on end and repel each other

1. Like charges repel
2. VdG ball has only one type of charge on it (negative) so Pom-pom must acquire like charges.
3. Pom-pom strands are light. If they do acquire a charge, electrostatic forces will be strong enough to move the strands

Anna demo

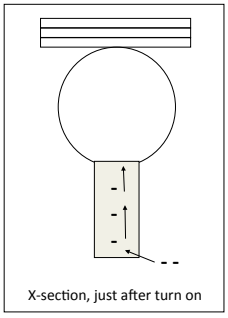
Attach Anna to top of VdG and turn on.
What will happen?

a) Nothing
b) Sparks will fly from Anna's head
c) Nasty smell of burning Anna will develop
d) Anna's hair strands will stand on end and repel each other

Demo of pie plates stacked on Van de graaff.

Turn on VG ⇒ put lots of extra electrons on sphere. What will happen to the plates?

a. Nothing, will stay there.
b. All will fly off at same time and stick together.
c. Top one will fly off, then next to top then next etc.
d. All will fly off at same time and separate.



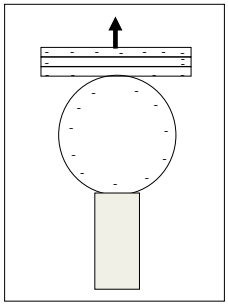
X-section, just after turn on

Demo of pie plates stacked on Vandegraaff.

Turn on VG, put lots of extra electrons on it. What will happen to the plates?

c. top one will fly off, then next to top then next etc.

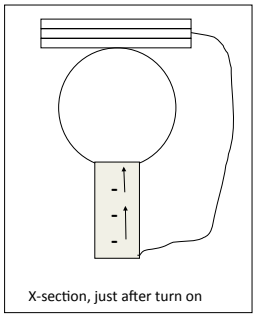
- ***Remember the forces are between electric charges, so think what charges would do.***
- Like charges repel, just like pom-poms
- Charges pileup on the edges of a conductor, so lots of charges pushed onto top plate
- $F = k q_1 q_2/r^2$ (Coulumbs law)
  So repulsive force largest on top plate and it flies off first



Now hook up wire to middle plate.

Turn on VG, what happens to the plates?

a. Nothing, will all stay there.
b. Top one will fly off, then next to top then next etc.
c. Only ones above where wire is hooked will fly off.
d. All above wired plate will all fly off at same time .
e. Something else



X-section, just after turn on

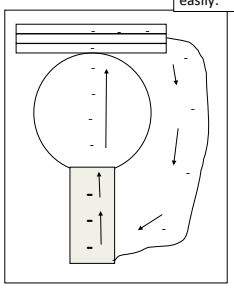
Now hook up wire to middle plate.

Turn on VG, what happens to the plates?

Wires allow electrons to flow easily.

a. Nothing, will all stay there.

- Forces involve charges. What will the charges do?
- Charges come up the belt, but then wire lets them flowback down to where they came from with almost no resistance.
- Extra charges cannot build up on Vandegraaff.
- No extra charges on pie plates so no force.



Balloon demo: Rub a balloon on sweater and stick it to the wall. What attracts the balloon to the wall?

After I have rubbed the balloon on my sweater, predict what charges will be on the balloon and on sweater

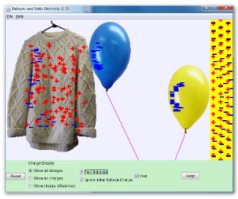
a. Both have extra + charges.
b. Both have extra - charges
c. Balloon has extra + or - charges, sweater neutral,
d. Sweater has extra + or - charges, balloon neutral
e. Either sweater has extra - and balloon extra + or balloon extra – and sweater extra +.

Look at Phet and find out……..

Answer is e:

Remember atoms are initially neutral
Electrons in sweater atoms are bound to atom less strongly than in balloon atoms
Rubbing allows balloon atoms to steal electrons, making balloon negatively charged (excess of electrons) and sweater positively charged

Balloon Sim



http://phet.colorado.edu/en/simulation/balloons

Rub a second balloon on the sweater.
The two balloons will ..

a. attract, b. repel, c. not exert a force on each other

b. repel:
• Balloons made of same material so must pick up same sign of charge from sweater
• Like charges repel

Move charged balloon close to wall. What will happen?

a. Wall is neutral (no extra + or -) so will not be affected.
b. - charges in wall will move away, + towards balloon
c. + charges in wall will move away, - towards balloon.
d. - charges in wall will move away, + don't move.

Rub a second balloon on the sweater.
The two balloons will ..

a. attract, b. repel, c. not exert a force on each other

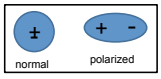
b. repel:
• Balloons made of same material so must pick up same sign of charge from sweater
• Like charges repel

Move charged balloon close to wall. What will happen?
d. - charges in wall will move away, + don't move.

.

• Negative charge on balloon repels –charge and attracted to + charge in the wall

• Atoms in wall become stretched (or polarized)



• Remember force between charges = $\frac{kq_Aq_B}{r^2}$

• Balloon is closer to + charges in wall than – charges, so force of attraction is stronger than force of repulsion