1 | An atom

We begin by recognizing the fact that **it's the electron that can move around in an atom.**.
For now, materials could be either **Conductors** or **Insulators.**

- **Conductors**
  - e^- move freely
  - Think! Metal
- **Insulators**
  - e^- cannot move freely
  - Think! Wood/Glass/Plastic

Charge properties

Different materials have tendencies to have a charge when rubbed

- Human hands => very positive when rubbed
- Fur => positive when rubbed
- Steel, Wood, Polyester => meh
- Plastics => negative when rubbed
- Silicon/Teflon => very negative when rubbed

Change Interactions

- Like changes tend to repel
- Different changes tend to attract

Rods and Paper

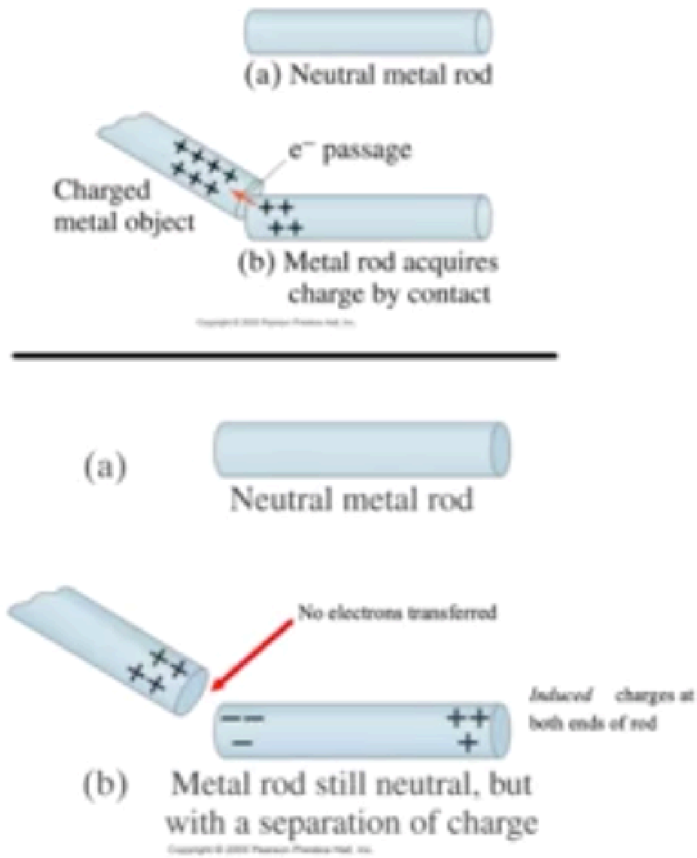

Figure 1: Screen Shot 2020-08-24 at 4.46.46 PM.png

Scenario 1

- Taking neutral rod + close, positively charged, rod
  - Electrons will move from the neutral rod to the charged rod
  - Balances the charge out

Scenario 2

- Taking neutral rod + slightly farther, positively charged, rod
  - The neutral rod "polarizes", repelling the positively charged protons off to one side while attracting all the electrons towards it
  - There is a net force of attraction to the "left" on the example image — towards the charged rod

Recall that per the physics[KB20200824111828] D1 At home Activity, pieces of paper sometime flow towards the charged rod, then back again. Why?

About how that works…

1. The charged rod polarizes the paper

2. The paper's newfound positive end attract with the plastic rod's negative end
3. The paper has a net positive force towards the rod, so it accelerates towards it
4. Electrons, once connected, tries to flow back onto the paper
5. The paper neutralizes, then falls to the ground
6. Repeat from (1)

The Electroscope

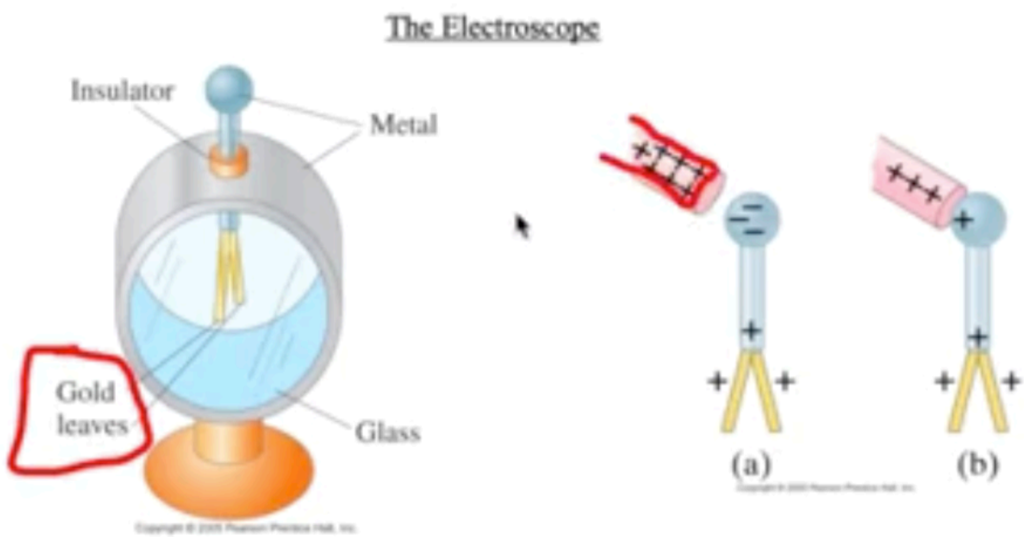

Figure 2: Screen Shot 2020-08-24 at 7.31.10 PM.png

About how this works…

1. Bring in some external charge near the electromitor (the ball-y part)
2. The rod becomes polarized, pushing the $+$ protons down towards the "gold leaves"
   - If the rod is not close enough to cause electron flow but is close enough to polarize…
     - Gold leaves temporarily push apart because positive repels positives
     - When charged rod removed, leaves come back
   - If the rod is close enough to cause e^- to flow out of the electromitor, making the whole rod more positive instead of a temporary polarization…
     - Gold leaves permanently (until somebody/the air discharges it, anyways) separated
     - When charged rod removed, leaves stay put

2 | **Quantifying electrical force!**

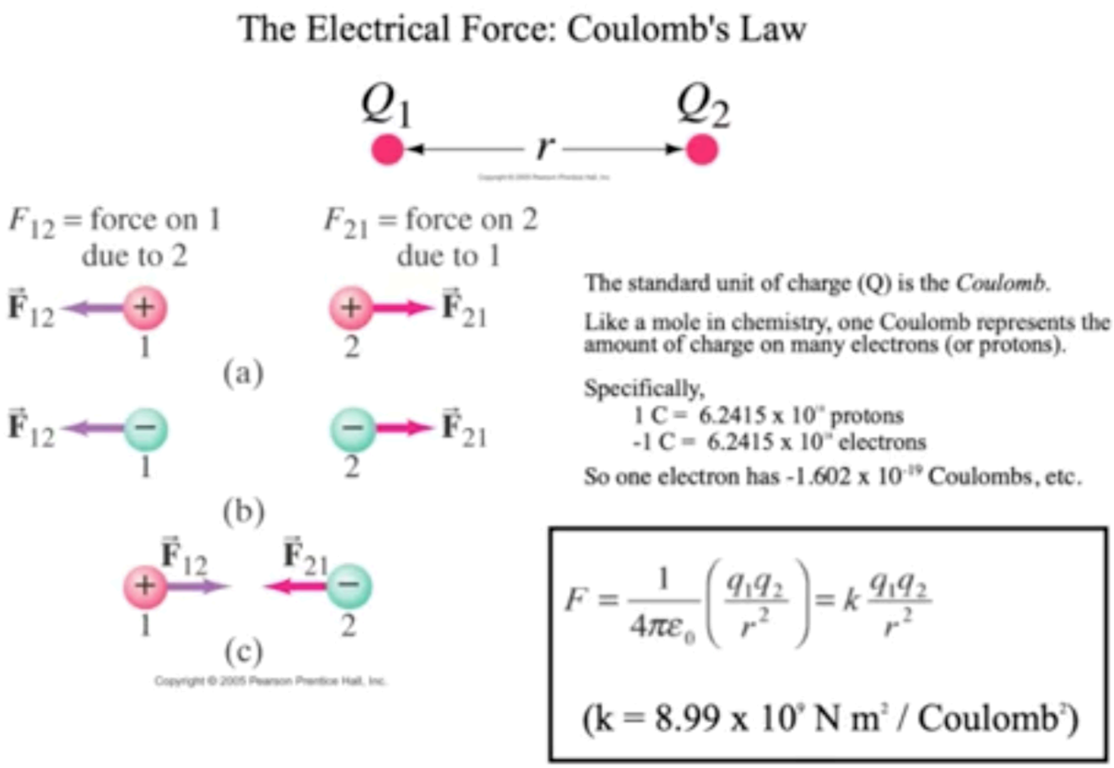

Figure 3: Screen Shot 2020-08-24 at 7.40.48 PM.png

- Electrical forces gets stronger as charge increases
- Electrical forces gets weaker as charge decreases

The magnitude of force between two charges is given by the Columb's Law

Definition 1 · **Coulomb's Law** $k\frac{q_1 q_2}{r^2}$
where k, a constant for change, q_1, change of first particle, q_2, change of second partical, r^2, distance squared

Note! The Standard Unit of Charge (Q) is the Coulomb — a representation for change for many electrons or many protons

Remember this!

Definition 2 · **Charge of an Electron** $-1.602 \times 10^{-19} Q$

Definition 3 · **k** $8.99 \times 10^9 \frac{Nm^2}{Q^2}$

E.M. forces, really, are two forces interacting with each other

Notice! Be careful with the signs when applying coulumbs law

- If resulting Coulomb force > 0, force is REPULSIVE (became you multiplied positive to positive or negative negative)
- If resulting Coulomb force < 0, force is ATTRACTIVE (became you multiplied positive to negative)

And now, a Guided Problem Solve

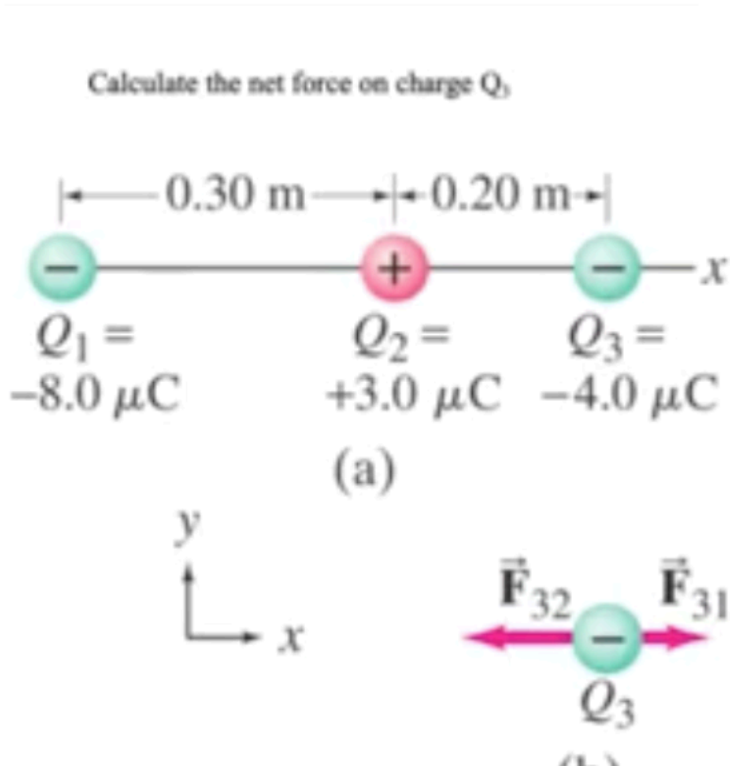

Figure 4: Screen Shot 2020-08-24 at 8.06.36 PM.png

Notice! This one is a little different because there are three charges.

We could see that, because of the fact that Q_2 is closer to $Q3$ then $Q1$ is and the two particles are pulling in different directions, we could infer that $||F_{32}||$ is larger then $||F_{31}||$. Because of this, we could find that Q_3 will have a net force "to the left" — in F_{32}'s direction.

And, because of that, we know that Q_3 will be accelerating towards the left. But **Notice**!, whenever Q_3 moves towards the left, the distances between the particles changed, meaning the force acting upon Q_3 changes! Meaning, Q_3's acceleration "to the left" is not constant. Unfortunately, then, no equation of kinematics for us :(.

Here's something! DNA Replication

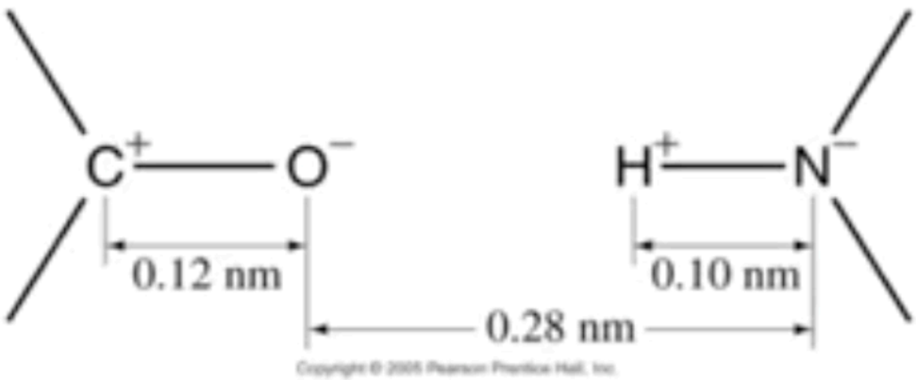

Figure 5: Screen Shot 2020-08-24 at 8.20.15 PM.png

The question is… Between these four atoms, *how many do we need to calculate to find if these two repel or attract?*

This is fairly simple. Because of the fact every force between each pair of atoms between these two elements needs to be calculated. So… 2 (on the left) times 2 (on the right) = 4.

If these repel, the don't combine. If they attract, of course they do.

3 | **Gravity!**

Each object has what's called **gravitational field.** Surrounding each object has what is effectively many tiny vectors getting weaker and weaker as you move away from the Earth. You could calculate the force of gravity just by knowing…

1. The mass of what you are calculating.
2. How far away is the other object's mass.

Then, out pops a value that tells you the magnitude of force that an object would exert on another object w.r.t. their mass that was dropped right where that vector was.

Remember, this is *not the gravitational force* between two objects. This is simply the *gravitational FIELD* of one. To calculate the force of gravity, simply use multiply the mass of the attractee to the gravitational field of the attractor, that is, $F_{grav} = M_{obj2} * GravField_{obj1}$.

Newton's Law of Gravitation

And for actually calculating the gravitational field, you will need

Definition 4 · **(A part of) Newton's Law of Gravitation** $Grav.Field = \frac{GM_{source}}{R^2}$
where G is a constant called "Gravitational constant"

For good measure, here's the two equations combined to form the full gravitational field.

Definition 5 · **Newton's Law of Gravitation** $F_{grav} = M_{target}\frac{GM_{source}}{R^2}$

It does not actually matter which object is the target and which one is the source. Because of an magical property called the "Multiplication is Commutative", swapping attractor and attractee will have the same numerical result for gravitational force. (*note! the field vectors are still different though*)

The units for *Gravitational Field* is $\frac{N}{kg}$, which, the keen-eyed will see, equals $\frac{m}{s^2}$, which, of course, is acceleration.

And now for a old piece of news:

Definition 6 · **(Roughly) Earth's Gravitational Field** $9.8\frac{N}{kg} = 9.8\frac{m}{s^2}$

Electric Field Striketh Back

You will notice that the *Electric Field* works very similarly to the *Gravitational Field*

To recall, Coulomb's Law looks like $F_{attraction} = k\frac{Q_1Q_2}{R^2}$, which is eerily similar to the Force of Gravity, $F_{grav} = G\frac{M_2M_2}{R^2}$.

And so, by the some token, we could also redefined electric force as:

Definition 7 · **Electric Force** $F_{attraction} = EQ_1$
where E is Q_2's electric field

Unsurprisingly, the units for *Electric Field* is $\frac{N}{C}$, and no, before you get excited, there is nothing it equals.

4 | **Electric Fields**

With masses, it's easy. Masses always *attracts* because negative mass doesn't exist (*yet*). But, with electric field, figuring out directions is harder.

So, we have two choices to dealing with directions:

1) Electric field of any Q has two values, one "attract field" and one "repel field"
2) Drawing a single vector $\vec{E}$, but remember that the direction of the vector depends on what's dropped in it

USE OPTION **2**.

In this manner, when we say, "this atom has a electric field vector in this direction", we mean two things

1. When a positive test change is dropped onto that vector, it will experience force in the same direction as the vector
2. When a negative "" "" "",'' "" "" the opposite direction as the vector

Illustrating Electric Fields

Yes, you could do this.

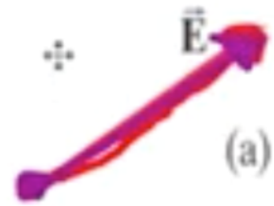

Figure 6: Oooh! A **single** vector!

And theoretically draw infinite metric tonnes of these around an object. But that's inefficient. We could instead think about electric fields as infinitely expanding in lines that travel from the center of the object outwards:

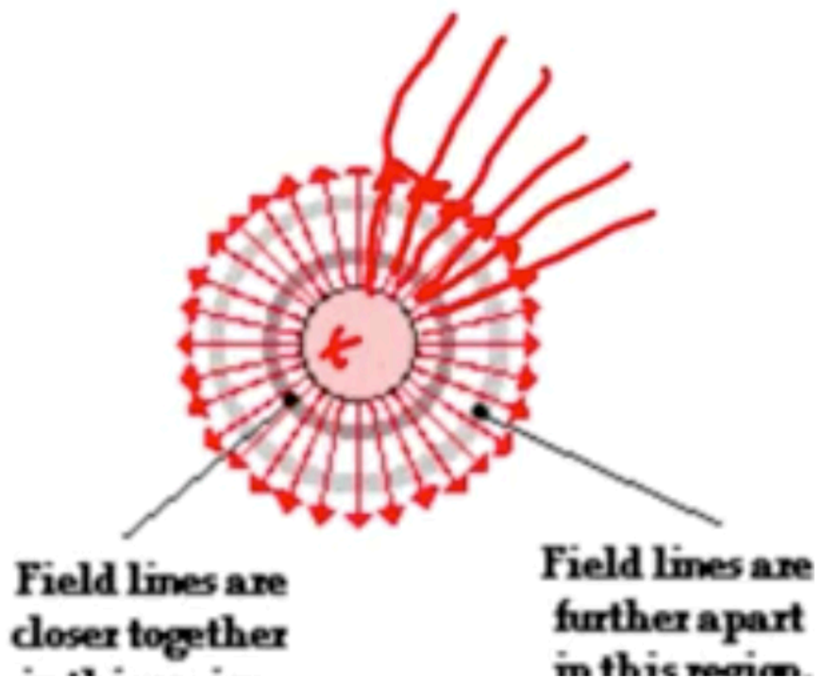

Figure 7: Screen Shot 2020-08-24 at 8.57.21 PM.png

Well, here's a problem. This diagram does not show the magnitude of the charge.

Well, fear not! Notice that there are shaded circles behind the red arrows? The density of these circles dictate the magnitude of the charge — the denser the circles, the higher the magnitude.

And now, lot's of these

Imagine if we had… Well… Lot's of these:

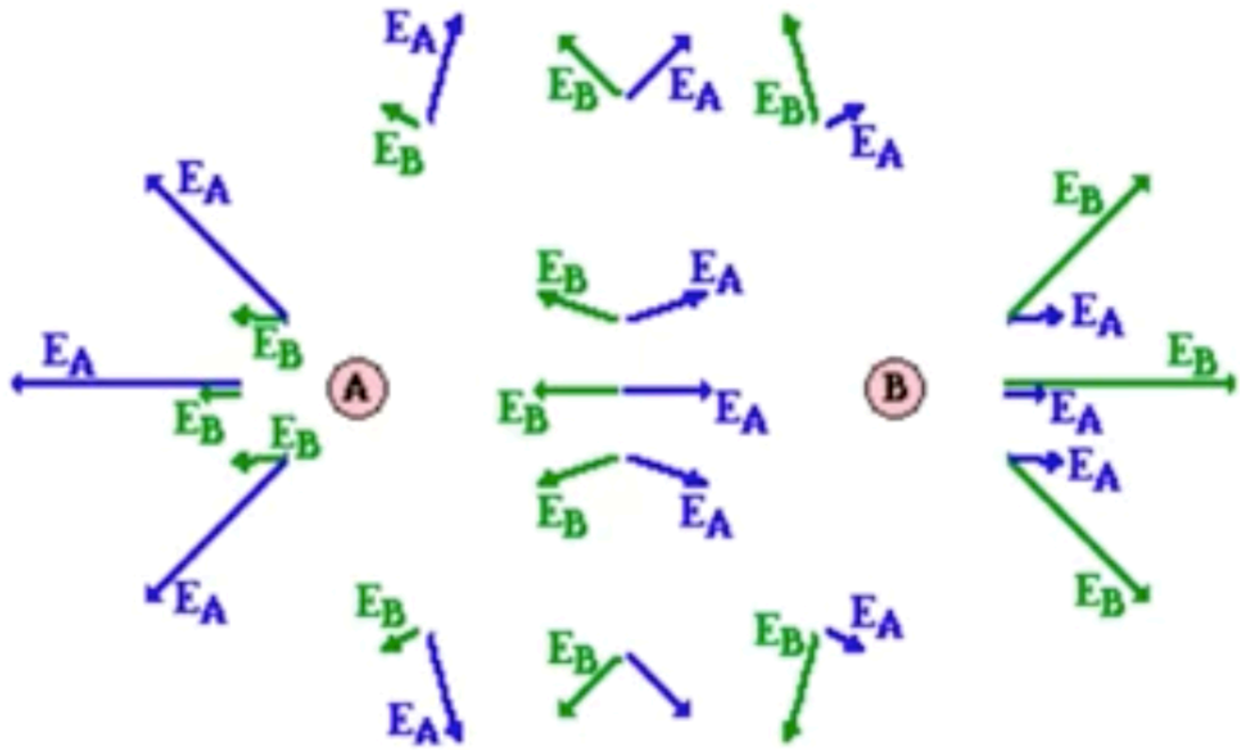

Figure 8: Screen Shot 2020-08-24 at 9.01.47 PM.png

In this diagram, A + B are both positive. The diagram, now, shows *both* electric field vectors for A and B. Take, for instance,

This tidbit:

If we connected it back to A and B, you will get:

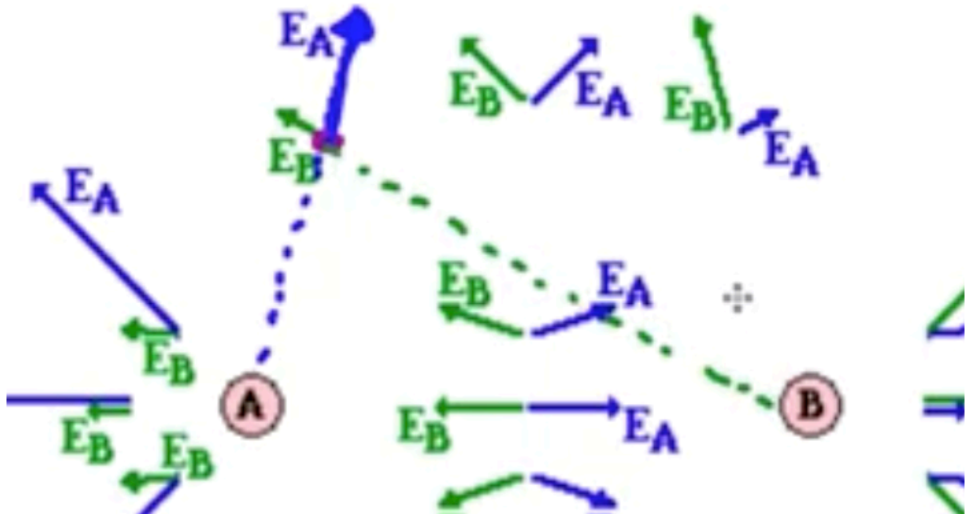

Figure 9: Screen Shot 2020-08-24 at 9.05.26 PM.png

As you could see, the force from B is smaller because the point is farther away from B.

Ok, now, let's see the *net* electric field by adding all of these vectors up:

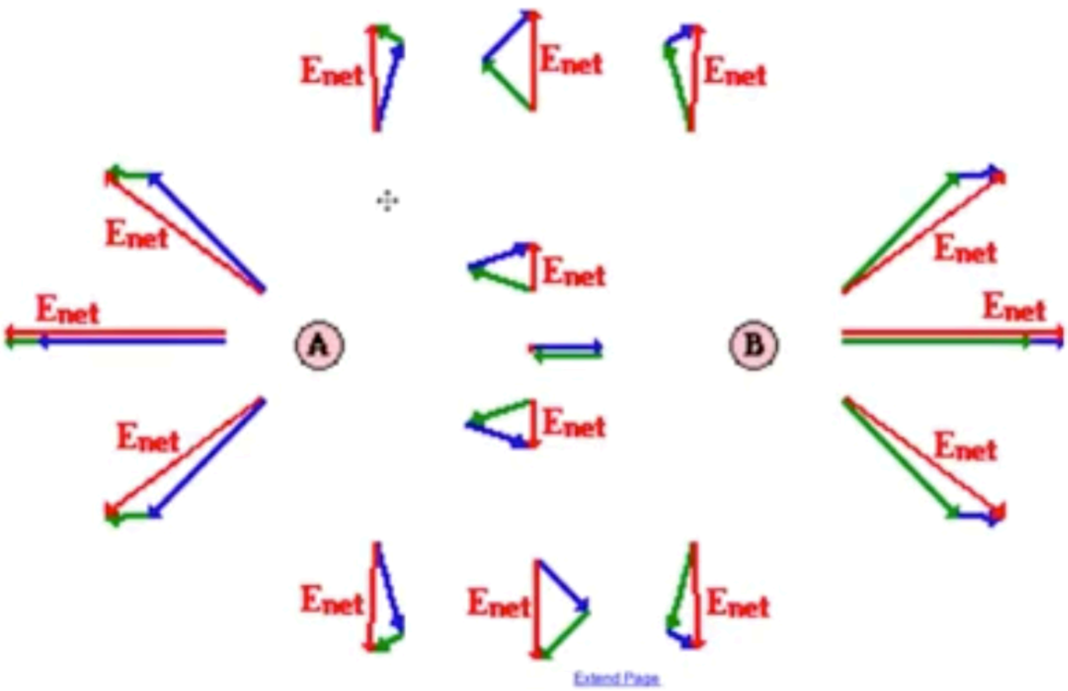

Figure 10: Screen Shot 2020-08-24 at 9.07.26 PM.png

Nice! You are, at this point, hopefully seeing something of a symmetry. Remember how we had two ways of drawing an electric field? That

1) You choose to draw an infinite amount of vectors, or
2) You draw lines from the center of each element outwards, connecting all the vectors

If we do option 2, you see this lovely image:

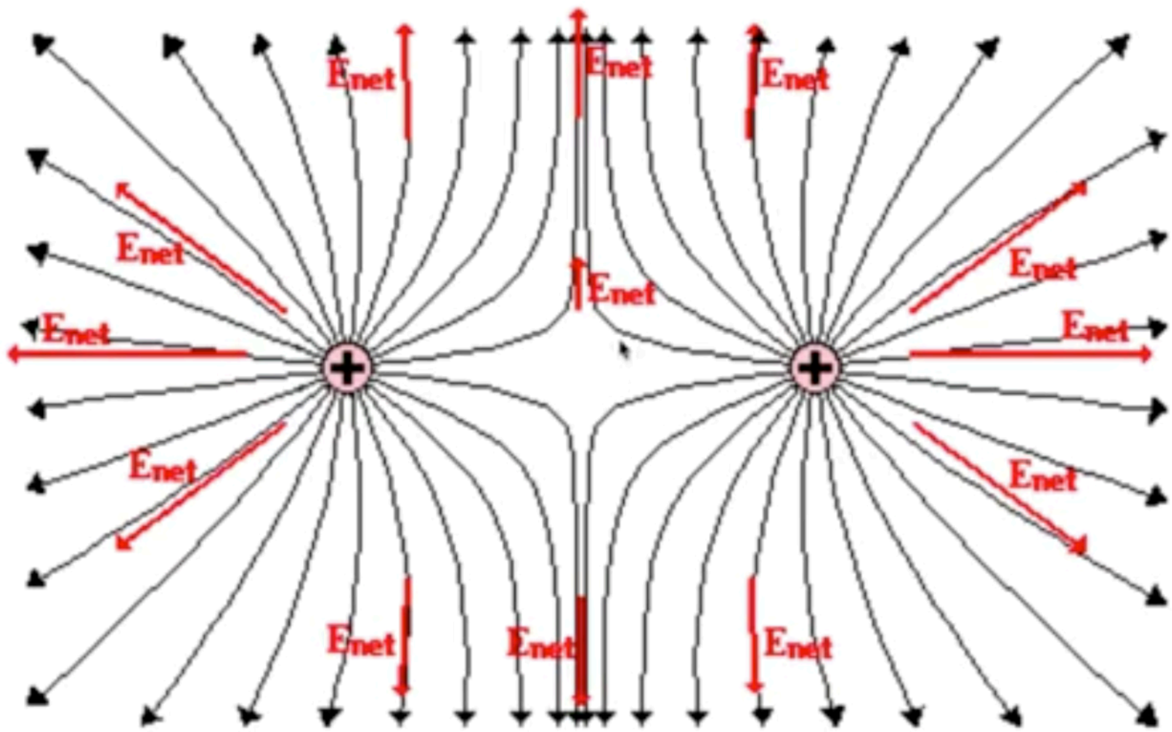

Figure 11: Screen Shot 2020-08-24 at 9.10.52 PM.png

Please, be also reminded of the fact that the world is 3D, making the diagram more like this:

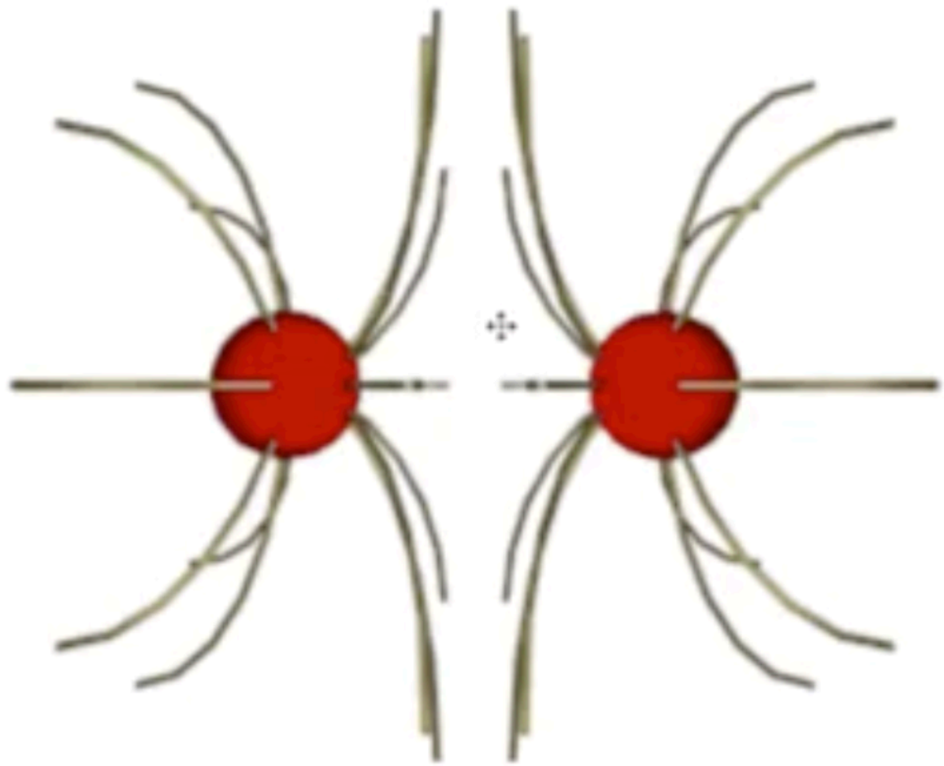

Figure 12: Screen Shot 2020-08-24 at 9.24.48 PM.png

Great. Lastly there are other possible configurations of charges apart from positive-positive, and they are as follows:

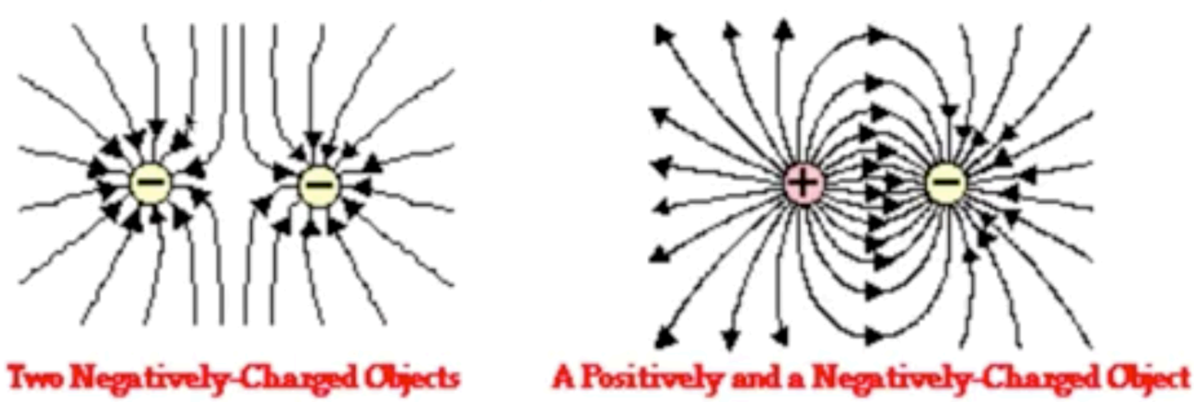

Figure 13: Screen Shot 2020-08-24 at 9.25.58 PM.png

As you could see. There is a lovely point (yes, it's actually a point, but people are lazy and don't to draw, say *infinite* field lines) in the middle of Neg-Neg and Pos-Pos electric field graphs with a lovely hole. At that hole, the field value is 0.

(Thanks Mr. Valdez!)

Here's a gallery of electric fields with unequal changes:

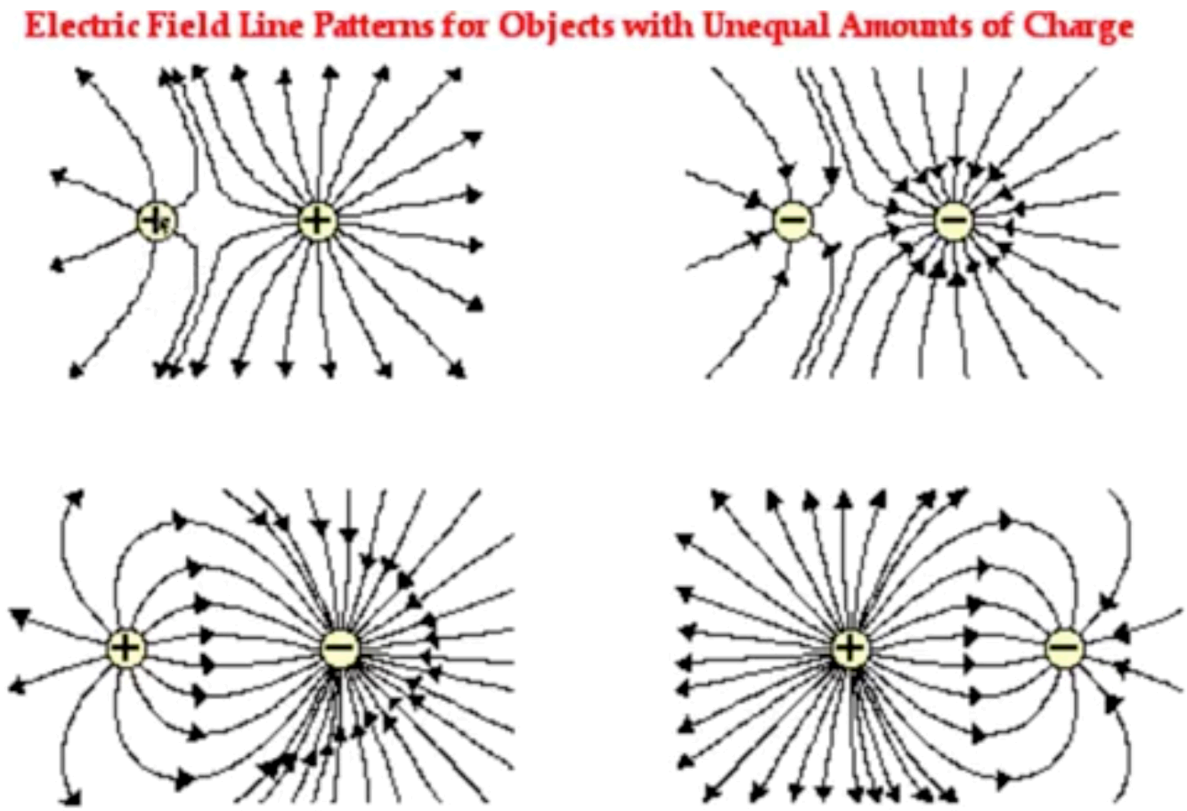

Figure 14: Screen Shot 2020-08-24 at 9.28.56 PM.png

As you could see, the higher amount of field lines, the higher is the strengths. If each charge's field "bends" towards the other, (i.e. particles that go *AAAAA I AM GOING TO OVERTAKE THE OTHER PARTICLE'S FIELD LINES*)

Conductors and Electric field

If the charges on a conductor are stationary…

1) E-field *in* the conducting material must be zero
    - Because, uhh…., the conductor is stationary, meaning no electron flow
    - So, without electric flow, you know that there is no motivation for electrons to flow, which means no electric field
2) At the surface of the conductor, if any E-field is present, it must be perpendicular to the surface
    - If you have a horizontal component, the conductor would be, well, *conducing* electricity, making it rather not static
    - If the E-Field is perpendicular, because we are in the Physics Vacuum, no charges will flow because it can't flow out of the conductor into something else

An now, something interesting

Take, a neutral conductor.!

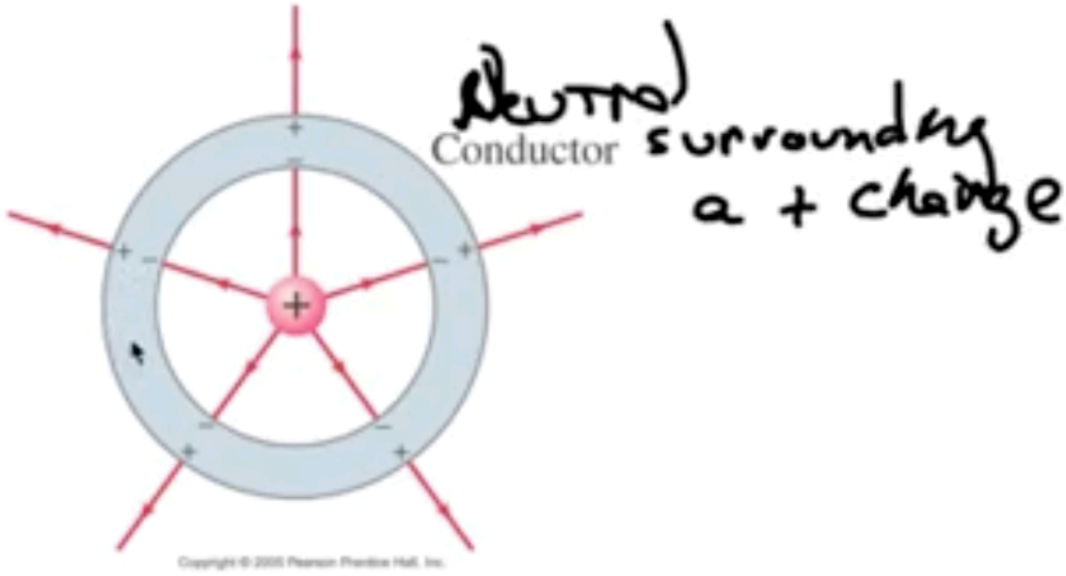

Figure 15: Screen Shot 2020-08-24 at 9.44.46 PM.png

At the point of the cursor, there would be an electric field cause by the central charge going outwards; at which point the following will happen…

1) The red (positive) charge attracts electrons to the inside of the tube
2) These newly electrons set up their own electric fields equal and opposite to the electric field by the central electron (because of the Electric Field Deux. Gravitational Field thing)

So, the conductor has a net electric field of 0. It's static.

Because of the fact that the neutral conductor had both 1) and 2) going on, there is no tangent changes to the conductor (**think!** rule 2 aforementioned), and only field lines that are perpendicular (emitted by the red, positive charge), will be passed out.