1/28/2019: Electric Forces & Test Charges

Monday, January 28, 2019 9:02 AM

Recall from last time that...

$$\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}$$

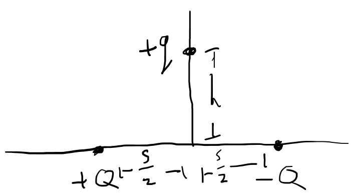
2 identical charged metal balls have charges +5uC and -1uC. They each feel a force of magnitude F. Now you bring them together so they touch, then move them back to their original positions. What is the magnitude of the new force?

INITIAL: $|F| = \frac{1}{4\pi\varepsilon_0}\frac{(5)(+1)}{r^2} = 5\frac{1}{4\pi\varepsilon_0 r^2}$

FINAL: $|F_f| = \frac{1}{4\pi\varepsilon_0}\frac{(2)(2)}{r^2} = 4\frac{1}{4\pi\varepsilon_0 r^2}$

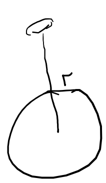
So, $|F_f| = 4\left(\frac{F}{5}\right) = \frac{4}{5}F$

Consider the charge configuration shown below. What is the direction of the net force on the +q charge?



The net force on the +q charge will be to the right. We can think of this problem in terms of x and y components of force. The y-component of force delivered by the +Q charge will be cancelled out by the symmetric component from -Q. However, both source charges will contribute to a right-ward force on the +q charge.

Now let's talk about Newtonian gravitational force...

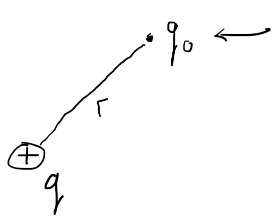


$$F_G = G\frac{M\cancel{m}}{r^2} = \cancel{m}g$$

$$\Rightarrow g = \frac{GM}{r^2}$$

We call this "little g" the gravitational field. So what would the electric field be?

Let's make an analogy to Coulomb's law...



Test charge

Symbol for electric field

$$\vec{F} = k\frac{q\cancel{q_0}}{r^2} = \cancel{q_0}E$$

$$\Rightarrow E = \frac{kq}{r^2}$$

Q: What is the business with this test charge?
A: Well, the test charge is assumed to be weak enough that it will not disturb significantly the distribution of charge. This idea of the test charge (which is always positive) will let us determine the

direction of the electric field.

Reading Questions

Q: In terms of spherical conductors, the textbook says that a charge applied to a spherical conductor becomes evenly spread out over the sphere, but if there were any imperfections in the sphere, which I am assuming there would be, would there be areas where the charge would not be uniform? Would there be a measurable effect?

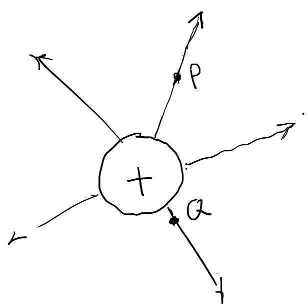
A: For stationary charges, the net force on the center of mass is zero (by shell theorem). So, the charges will distribute according to this fact. With a radially symmetric shape (i.e. a sphere), the charges distribute evenly. But with some irregular shape, they will configure so as to follow shell theorem.

Q: What if the rod was a conductor and not an insulator?
A: A lot of insulators can be charged with friction. But, they don't discharge them to the body of the person handling the rod as easily as a conductor! If you tried this experiment with a conductor, the electrons would flow through the rod, through the body, and into the ground. So, the effect on the rod would be basically no net charge accumulation.

Test Charge	Point Charge
Positively charged	Can have any charge
Weakly charged	Can have any charge
No ability to effect field lines	Can effect field lines

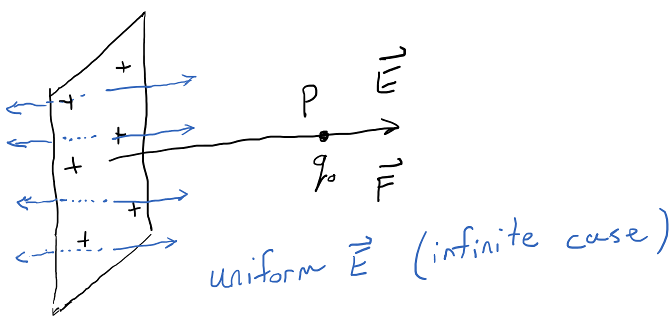
Electric Flux: a term used to calculate the number of field lines.

Direction of Electric Field



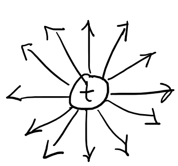
Electric field lines: important for two things.
1. The direction of the field line is telling you the direction of the electric field at any point.
2. The number of field lines (in effect density) is telling you the strength of the field at any point.

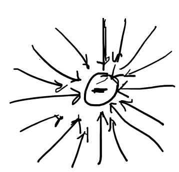
- Note: the field lines point outward, because this is a positive charge. Also, at the point Q, a stronger electric field exists than at point P (more dense field lines, too!).



Of course, in real life there are not infinite surfaces. So, we can use this approximation of uniform electric field only **far away from the boundaries**. At the edges, things get more complicated.

Isolated positive charge
(trick: assume that there is a negative charge at infinity)



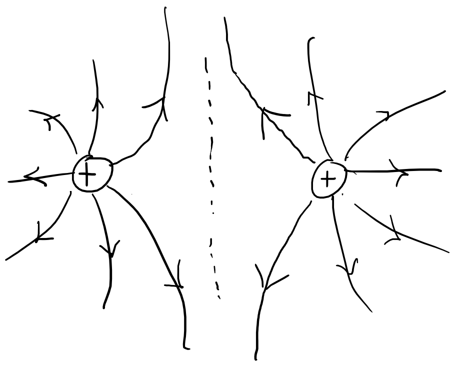


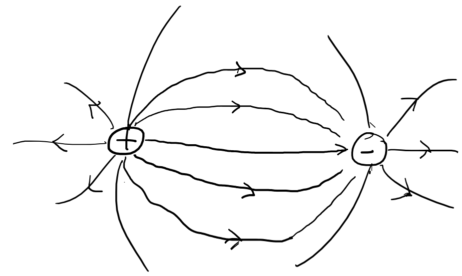
Isolated positive charge
(trick: assume that there is a positive charge at infinity)

Electric field lines always go from positive --> negative

Two positive charges.

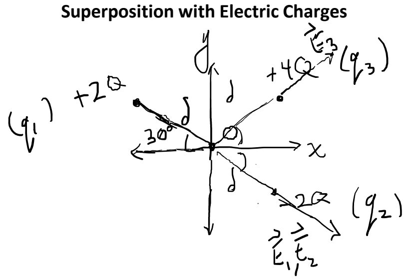
Two charges of different magnitude (a.k.a. dipole).





Note: two negative charges would be the same field line structure, but would be going in the opposite direction!

Superposition with Electric Charges



$$|E_1| = k\frac{2Q}{d^2}, \quad |E_2| = k\frac{2Q}{d^2}, \quad |E_3| = k\frac{4Q}{d^2}$$

$$\sum \vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$$

- UPWARD, RIGHT-WARD DIRECTION.
- y-COMPONENT EQUAL, OPPOSITE TO $E_{1,y} + E_{2,y}$

SAME STRENGTH, SAME DIRECTION.

So, $$\sum \vec{E} = \sum \vec{E}_x = \vec{E}_1 \cos 30° + \vec{E}_2 \cos 30° + \vec{E}_3 \cos 30° = 2\vec{E}_3 \cos 30° \Rightarrow \boxed{\vec{E}_3 = \frac{4kQ}{d^2}\hat{y}}$$