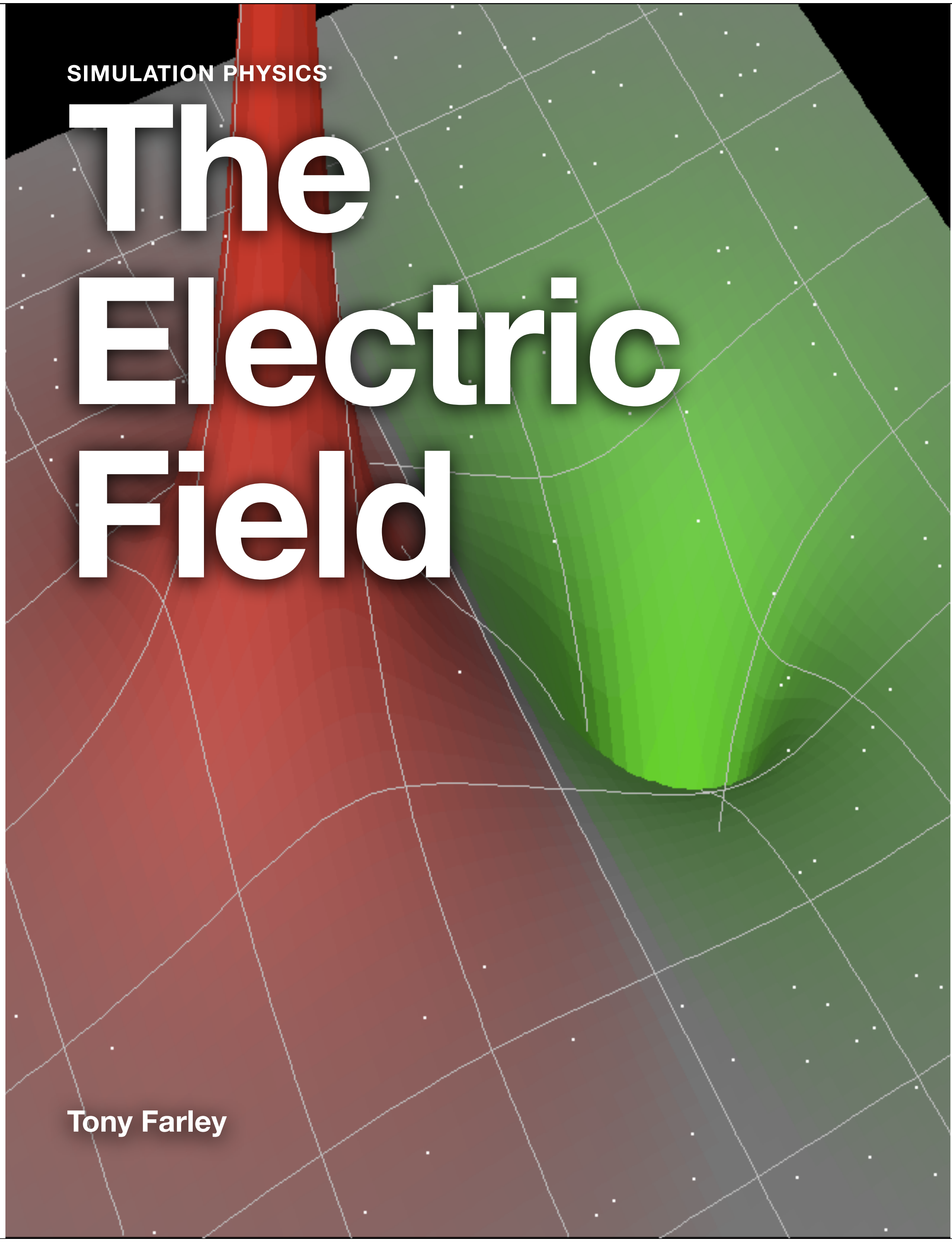

SIMULATION PHYSICS
The Electric Field
Tony Farley

Welcome

This book was written for the students in my high school physics classes, for students in other physics courses, and for anyone wanting to learn physics in an interactive and engaging way. So much of physics is theoretical and untouchable, I think the only way to really understand is to push and pull on the equations through simulation. That is why my first volume is on the Electromagnetic force. There is so much to play with!

However, the use of simulations throughout this book requires a system that can use Java and even Flash sometimes. The iPad and iPhone cannot. Therefore, much of the text will be exported as .pdf files with embedded links to the simulations. These can be read and the linked simulations will work with a computer. I also have a website where the text can be read on a computer. The site and the pdf files are at farleyphysics.com along with much more.

As an iBook, there will be plenty of interactive graphics, animations, and videos within the text. These will work on an iPhone/iPad, but will not work in the pdf. I wish everything worked together and had the same functionality, but it doesn't. I am trying to make both ways of reading this text valuable, but believe me, any frustration you feel is frustration that I feel as well. My apologies to you in advance for any frustration this causes.

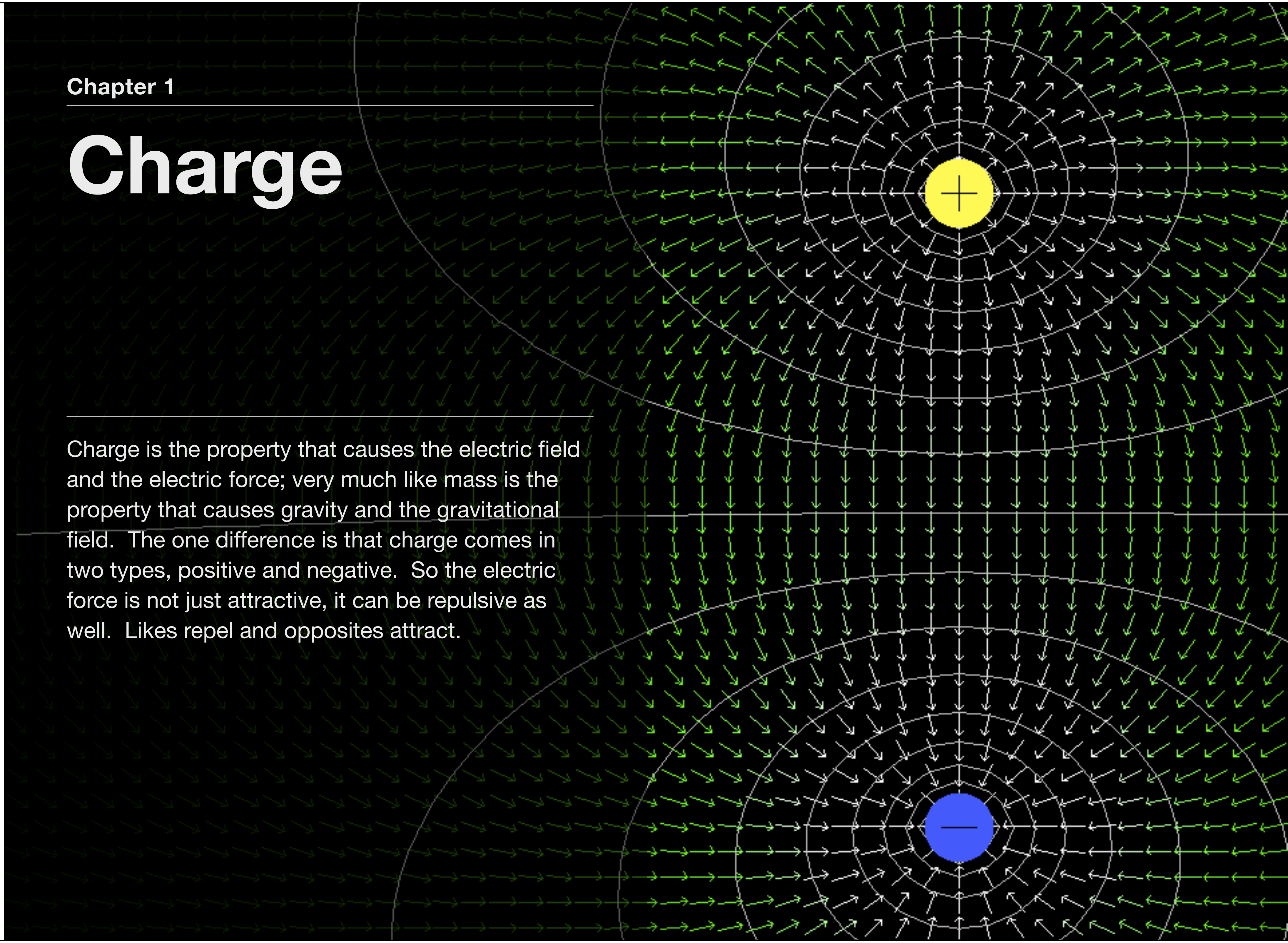
If you enjoy the book and would like to see it improve with more simulations on the iPad more functionality, and more topics, please support the effort by donating on the website.

Thank you,

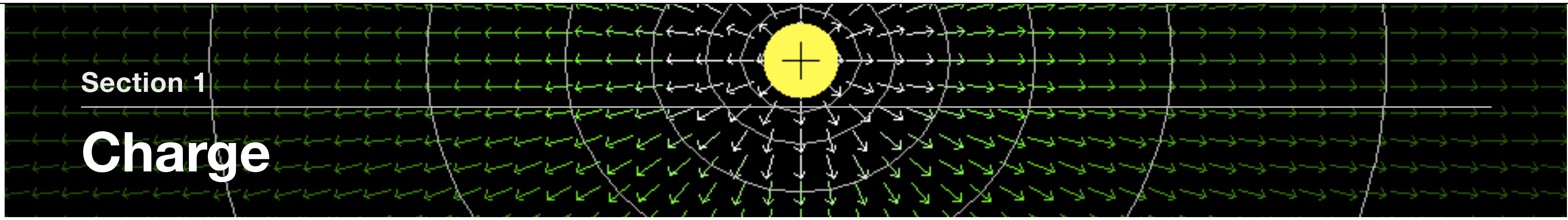
Tony Farley
San Leandro High School

Chapter 1

Charge



Charge is the property that causes the electric field and the electric force; very much like mass is the property that causes gravity and the gravitational field. The one difference is that charge comes in two types, positive and negative. So the electric force is not just attractive, it can be repulsive as well. Likes repel and opposites attract.



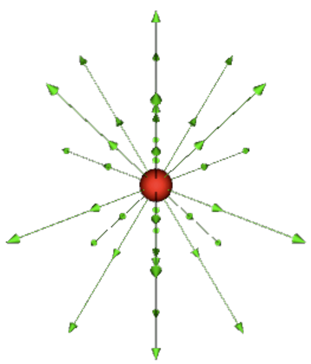
Section 1

Charge

THINGS TO KNOW

1. **Charge is either positive or negative**
2. **Charged particles are the sources of electromagnetic fields**
3. **Charged particles are subject to the forces of electromagnetic fields from other**

Interactive 1.1 3D Representation of the electric field from a positive charge.



The electric field always points away from a positive charge.

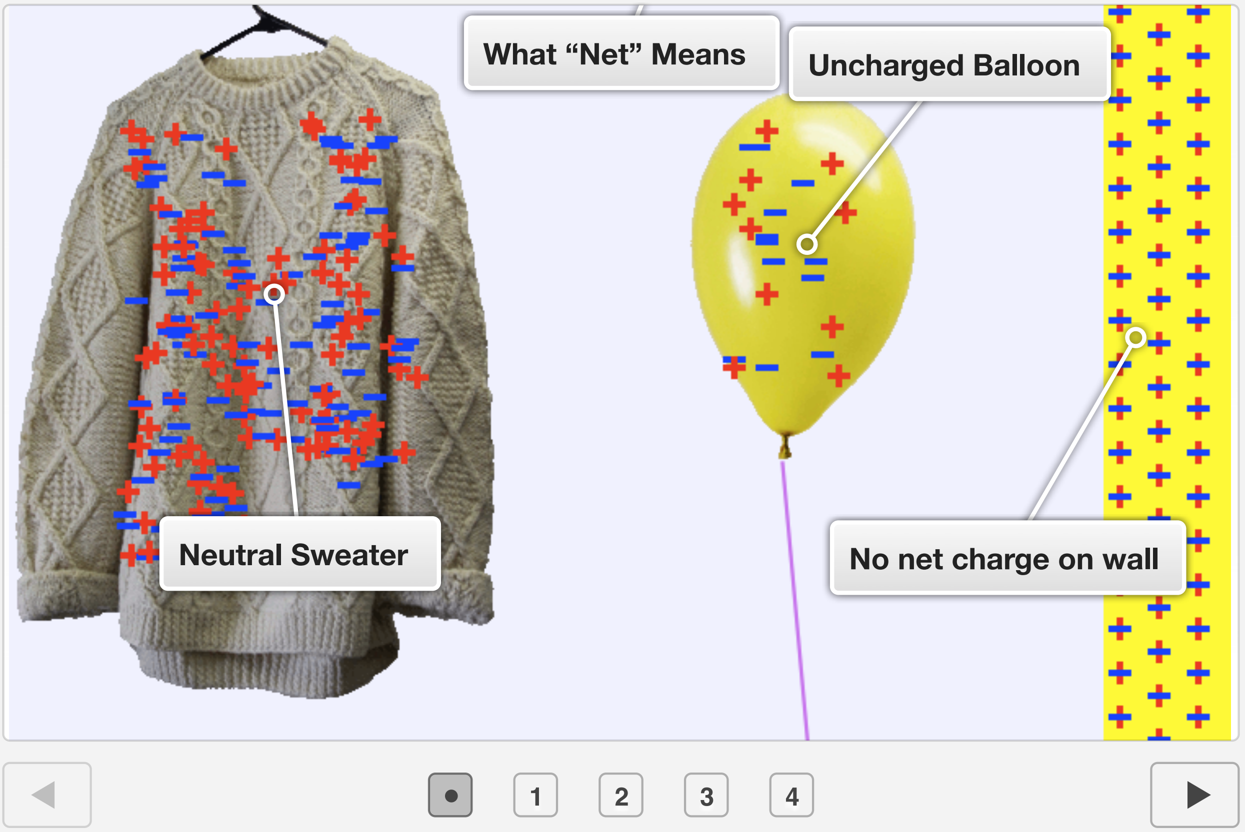
Charged particles are everywhere, in everything. Every atom that makes up you or anything else, contains charged particles. Every atom is made of positive particles called protons and negative particles called electrons. Usually, each atom has the same number of positive charges as negative charges, so they balance each other and cancel each other out. That's why you and I are not attracted or repelled by the electromagnetic force; we have zero charge. That's a good thing, because the electromagnetic force is 10^{41} times as strong as the gravitational force. That's a lot. That means that if you took all of the negative charge out of your body and took all the positive charge out of the earth, the force on you from the earth would be trillions of trillions of trillions of trillions of times as much as your weight.

So if the electromagnetic force is so strong, why don't you experience it in everyday life? You do, you just take it for granted. Everything is held together by the electromagnetic force. The atoms in the ground you stand on are held together by it. Your atoms are held together by it, and the buildings you live in are held together by the electromagnetic force. Without the electromagnetic force, the universe would just be a fog of particles that fly around and never interact.

But you can become charged. If you have ever been shocked when you reached for a doorknob or another person, that is charge that has built up on you, jumping through the air and onto the doorknob or the other person. You become charged, usually by rubbing against something that either takes electrons away from you or gives up electrons to you. Either way, you are charged, and you can now perform feats that are almost magical. You can levitate a balloon with a wand, lift pieces of paper off a table from a distance, and zap your friends with just a touch.

The following illustrations show how rubbing moves charges around, causing objects to become charged. Those charged objects can then be used to force other objects around or to charge them.

Interactive 1.2 Most objects have no net charge

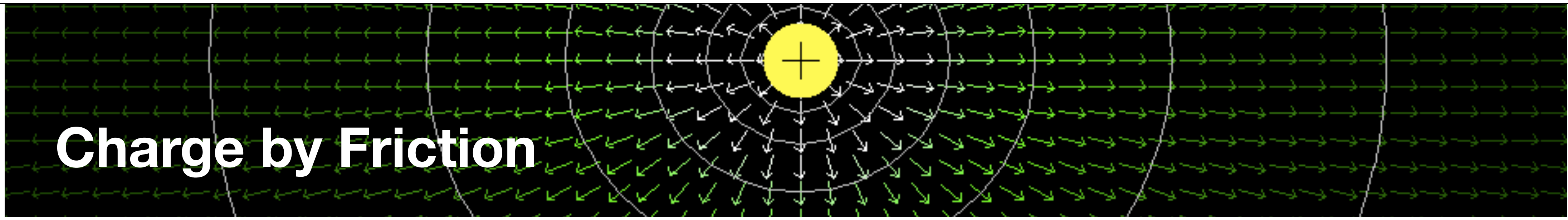


Interactive 1.2 shows how every object contains both positive and negative charges. Most objects contain an equal amount of positive and negative charges, making the net charge zero. Net charge is just all the charges added up. If there are just as many negative charges as positive, the net charge is zero.

The Coulomb

The unit of charge is the Coulomb, named after french physicist Charles-Augustin de Coulomb. Coulomb (pronounced Cool-loam) developed Coulomb's Law, which is the law that explains the force between charges. We will study Coulomb's Law in a later chapter, but it is very similar to the equation for gravity, the electric force is directly proportional to charge and proportional to the inverse square of the distance between the charges. A Coulomb, abbreviated with a large C, is a lot of charge. One electron has -1.6 x 10^{-19} C of charge. So it takes 6 x10^{18} electrons to make up one Coulomb of charge. That may seem like a lot, but a penny contains 1000 Coulombs worth of electrons.

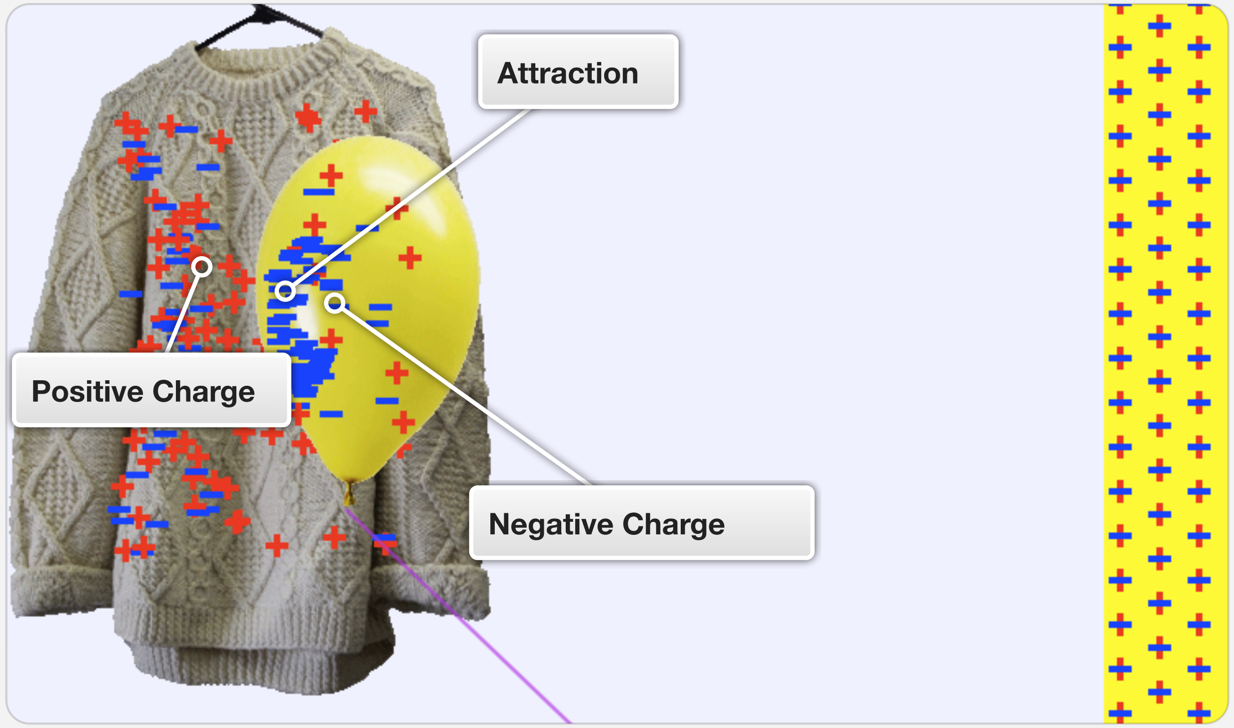
The interactive above is from the PhET Balloons and Static Electricity Simulation. If you are viewing this book in pdf form, click the highlighted link to view the simulation in a browser. Grab the ballon and rub it up against the sweater and watch the electrons move.

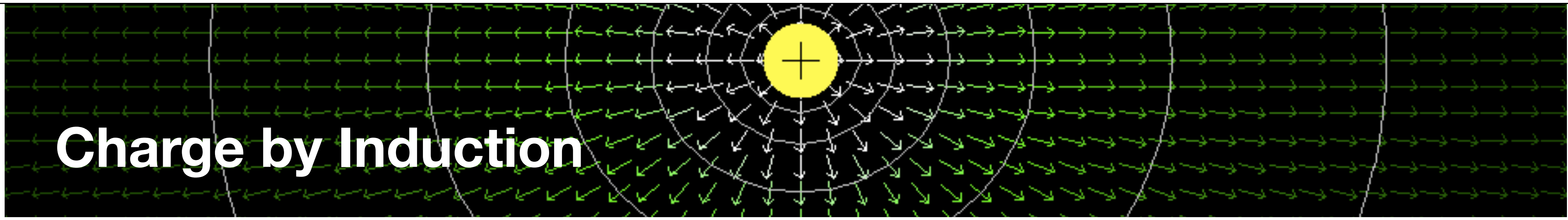


Charge by Friction

While the forces between charges can be very strong, the amount of force needed to remove one single electron from an atom is very small. So the action of rubbing two objects together creates enough frictional energy to remove electrons from one object and place them on another. Interactive 1.3 below shows how rubbing a balloon against a sweater removes electrons from the sweater, causing the net charge of the sweater to be positive. The extra electrons on the balloon cause the net charge on the balloon to be negative. The balloon and sweater are now attracted to each other via the electromagnetic force.

Interactive 1.3 Rubbing Moves Charge

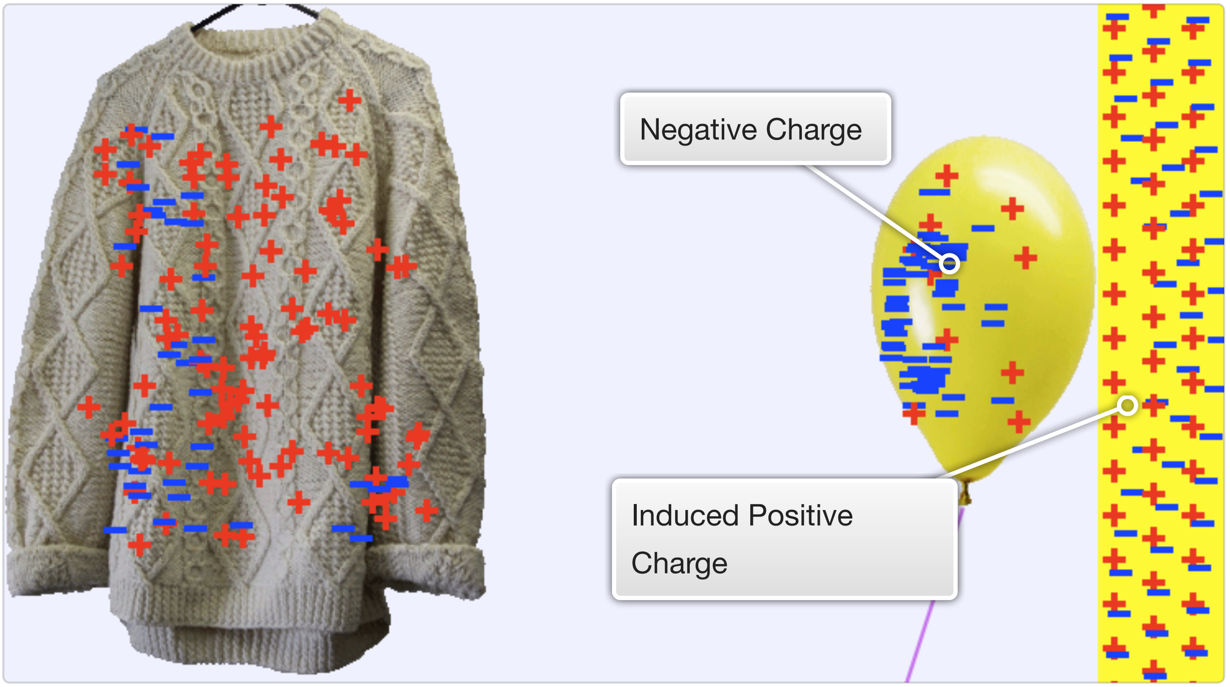




Charge by Induction

Bring the negatively charged balloon near the wall and the negative charges on the balloon repel electrons in the wall. Since the electrons in the wall are pushed away from their positive charges, the wall now has a positive charge on its surface. The balloon will now be attracted to the wall. This is called charge by induction. You induce the charge on the wall by pushing the charged balloon toward the wall.

Interactive 1.4 Bringing the balloon near the wall induces a positive charge



Questions

1. What are the two types of charge?

2. The electric field always points away from what kind of charge?

3. The electromagnetic force is how much stronger than the gravitational force?

4. Most objects have what net charge?

5. What is the unit of charge?

6. What is the charge of an electron?

7. What can rubbing two objects do?

8. An object with more negative charges than positive charges has what net charge?

9. Things with opposite charge do what?

10. Objects with like charge do what?

11. Bringing a charged object near a neutrally charged object can charge that object. What is this called?

Run this simulation and answer the questions below.

1. Rub the balloon against the sweater and explain what happens to the sweater and the balloon.

2. Release the balloon between the sweater and the wall. What happens? Explain why in terms of charge. Draw a picture and write this as a statement explaining what is happening.

3. Bring the balloon toward the wall and explain what happens to the negative charges in the wall and what happens to the positive charges. Draw a picture and write this as a statement in your notes that will help you remember it on a quiz.

4. Is the balloon attracted more to the sweater or to the wall? Why?

5. What did you do to figure #4 out?

6. Reset and add two balloons. Rub them both against the sweater. Do they attract or repel each other? Why?

Chapter 2

Field

The electric field is much like the gravitational field, except there are positive and negative charges meaning the forces can be attractive or repulsive. Opposites attract and likes repel. Also, the electric force is millions of times as strong as gravity. Meaning a little bit of charge can have a huge effect on another little bit of charge.