Stop Faking It!

Finally Understanding Science So You Can Teach It

Electricity and Magnetism

NSTA press
NATIONAL SCIENCE TEACHERS ASSOCIATION
Arlington, Virginia

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ART AND DESIGN Linda Olliver, Director
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06 05 04 4 3 2 1

Library of Congress Cataloging-in-Publication Data
Robertson, William C.
Electricity and magnetism : stop faking it! finally understanding science so you can teach it/by William C. Robertson.
p. cm.
Includes index.
ISBN 0-87355-236-9
1. Science—Study and teaching—Popular works. 2. Science—Methodology—Popular works. I. Title.
Q181.R568 2004
537'.07'1—dc22
2004013339

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Contents

Preface

The book you have in your hands is the fifth in the *Stop Faking It!* series. The previous four books have been well received, mainly because they stick to the principles outlined below. All across the country, teachers, parents, and homeschoolers are faced with helping other people understand subjects—science and math—that they don't really understand themselves. When I speak of understanding, I'm not talking about what rules and formulas to apply when, but rather knowing the meaning behind all the rules, formulas, and procedures. I *know* that it is possible for science and math to make sense at a *deep level*—deep enough that you can teach it to others with confidence and comfort.

Why do science and math have such a bad reputation as being so difficult? What makes them so difficult to understand? Well, my contention is that science and math are *not* difficult to understand. It's just that from kindergarten through graduate school, we present the material *way* too fast and at too abstract a level. To truly understand science and math, you need *time* to wrap your mind around the concepts. However, very little science and math instruction allows that necessary time. Unless you have the knack for understanding abstract ideas in a quick presentation, you can quickly fall behind as the material flies over your head. Unfortunately, the solution many people use to keep from falling behind is to *memorize* the material. Memorizing your way through the material is a surefire way to feel uncomfortable when it comes time to teach the material to others. You have a difficult time answering questions that aren't stated explicitly in the textbook, you feel inadequate, and let's face it—it just isn't any fun!

So, how do you go about *understanding* science and math? You could pick up a high school or college science textbook and do your best to plow through the ideas, but that can get discouraging quickly. You could plunk down a few bucks and take an introductory college course, but you might be smack in the middle of a too-much-material-too-fast situation. Chances are, also, that the undergraduate credit you would earn wouldn't do the tiniest thing to help you on your teaching pay scale. Elementary and middle school textbooks generally include brief explanations of the concepts, but the emphasis is definitely on the word *brief*, and the number of errors in those explanations is higher than it should be.

Finally, you can pick up one or fifty "resource" books that contain many cool classroom activities but also include too brief, sometimes incorrect, and vocabulary-laden explanations.

Given the above situation, I decided to write a series of books that would solve many of these problems. Each book covers a relatively small area of science, and the presentation is slow, coherent, and hopefully funny in at least a few places. Typically, I spend a chapter or two covering material that might take up a paragraph or a page in a standard science book. My hope is that people will take it slow and digest, rather than memorize, the material.

This fifth book in the series is about electricity, magnetism, and electrical circuits. To best understand the material, it's best to have lots of semi-expensive material to play around with. Assuming most of us (writers and readers!) don't have the big bucks to spend, we've come up with a great alternative, which is special software that allows one to simulate simple to complex electrical circuits on the computer (see page xi for details). Aside from the fact that this software allows us to build circuits that would otherwise cost lots of money, we have the added advantage that electrocution is a remote possibility at best. On top of those values, you get a genuinely cool piece of software that is just plain a fun toy.

There is an established method for helping people learn concepts, and that method is known as the **learning cycle**. Basically, it consists of having someone do a hands-on activity or two, or even just think about various questions or situations, followed by explanations based on those activities. By connecting new concepts to existing ideas, activities, or experiences, people tend to develop understanding rather than memorization. Each chapter in this book, then, is broken up into two kinds of sections. One kind of section is titled, "Things to do before you read the science stuff," and the other is titled, "The science stuff." If you actually do the things I ask prior to reading the science, I guarantee you'll have a more satisfying experience and a better chance of grasping the material.

It is important that you realize this book is *not* a textbook. It is, however, designed to help you "get " science at a level you never thought possible, and also to bring you to the point where tackling more traditional science resources won't be a terrifying, lump-in-your-throat, I-don't-think-I'll-survive experience.

Dedications

This being the fifth book in this series, I feel a set of dedications are long overdue. I first dedicate this book to Marie Galpin, who taught me that it was okay to be different and to pursue my own goals. You always accepted me for who I was when I doubted that. Thank you, Marie.

Second, I would like to thank David Beacom, Claire Reinburg, and the rest of the kind and efficient group at NSTA Press for taking a chance on this series. They trusted that teachers would find the series entertaining and that it would turn out to be one of those rare commodities—a fun medium for learning.

I would like to thank Brian Diskin for proving the old adage wrong—you *can*, in fact, tell a book by its cover. As I surreptitiously watch people browse through the titles at the NSTA conventions, they rarely pass by the *Stop Faking It!* books without at least picking them up and thumbing through the pages. The humor and overall style is apparent from the book covers and from the obvious quality of the page-by-page illustrations. Brian's art entices the reader to dig just far enough to see what else the book has to offer.

Finally, I would like to thank my wife, Jann, and my children, Sara and Jesse, for putting up with the fact that Dad has to work way too many nights and weekends in order to finish these silly books. All three also serve as my best critics.

Acknowledgments

The *Stop Faking It!* series of books is produced by the NSTA Press: Claire Reinburg, director; Andrew Cocke, project editor; Linda Olliver, art director; Catherine Lorrain-Hale, production director. Linda Olliver designed the cover from an illustration provided by artist Brian Diskin, who also created the inside illustrations.

This book was reviewed by Daryl Taylor (Williamstown High School, New Jersey); Kenneth Thompson (Emporia State University, Kansas); and Larry Kirkpatrick (Montana State University).

About the Author

As the author of NSTA Press's *Stop Faking It!* series, Bill Robertson believes science can be both accessible and fun—if it's presented so that people can readily understand it. Robertson is a science education writer, reviews and edits science materials, and frequently conducts inservice teacher workshops as well as seminars at NSTA conventions. He has also taught college physics and developed K–12 science curricula, teacher materials, and award-winning science kits. He earned a master's degree in physics from the University of Illinois and a PhD in science education from the University of Colorado.

About the Illustrator

The soon-to-be-out-of-debt humorous illustrator Brian Diskin grew up outside of Chicago. He graduated from Northern Illinois University with a degree in commercial illustration, after which he taught himself cartooning. His art has appeared in many books, including *The Golfer's Personal Trainer* and *5 Lines: Limericks on Ice*. You can also find his art in newspapers, on greeting cards, on T-shirts, and on refrigerators. At any given time he can be found teaching watercolors and cartooning, and hopefully working on his ever-expanding series of *Stop Faking It!* books. You can view his work at *www.briandiskin.com.*

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Chapter

Small Sparks to Get Us Going

Judging from the title of this chapter, you might guess that I'm starting off this book with a few basics about electricity, and you'd be right. Other than that great guess of yours, you might be wondering why the book is about electricity *and* magnetism. Is there any special reason to put these two areas of science together? The answer is yes. In fact, the connection between electricity and magnetism is so strong that you can actually view them as the same thing. You'll have to wait until Chapter 4, though, to see that connection. Sorta gets you all anxious and nervous waiting for that, huh? In the meantime, let's get moving on those electricity basics.

Actually, I'm going to warn you about something first. For many of the activities I'll be asking you to do in this and in the next chapter, it's best if you do them when the humidity isn't very high. What that means is that these activities will work best in the winter (when it's generally not as humid), and will work best if you live in places like Colorado, Arizona, Nevada, and California. I'm not saying these activities *won't* work where it's really humid, but rather that you won't get dramatic results. Of course, if you live someplace like Houston or Tampa, it's the middle of August, and the skies are threatening rain, maybe you should put this book away and try another day.

Things to do before you read the science stuff

Grab a balloon, blow it up, and tie it off. Look at yourself in a mirror as you rub the balloon vigorously on your hair and then slowly pull the balloon away from your head. You should get a result something like that shown in Figure 1.1. By the way, this won't work if your hair is wet or if you use hair spray or gel on your hair. Also, don't even think about getting any results if you have a buzz cut or dreadlocks or a shaved head (duh!). Notice that if you pull the balloon a long ways from your hair, your hair relaxes back down. Bring the balloon slowly toward your hair and there's an attraction again.

Figure 1.1

Now that you have this fun trick, why not share it with a friend? Get that friend and make sure he or she has hair that satisfies the previous requirements (not wet, no gel, etc.). Rub the balloon on *your* hair and then hold the balloon near your friend's hair. Not much happening? Try holding the balloon near *your* hair to convince you the trick still works. Just for closure, have your friend rub the balloon on his or her hair and then place the balloon near each of the two heads in the room. What happens?

Blow up a second balloon and tie it off. Rub both of your balloons on your hair, or on a carpet if you don't have the right kind of hair for this thing. With the balloons resting in the palms of your hands, slowly bring the balloons together. When they get very close together, you should notice something happening, such as the balloons pushing each other away.

Finally, shuffle your feet across a carpeted room (this works best if you're wearing thick socks or tennis shoes) and then touch something metal. If the air is dry enough, you'll get a nice shock. If it's too humid, just think back to the last time you got a shock from touching a doorknob or a drinking fountain. Of course if you're not crazy about giving yourself a shock, you can just rub your balloon on the carpet and then hold it near a metal doorknob. Listen carefully and you'll hear a spark jump between the balloon and the doorknob. Darken the room and you can *see* the spark jump. Cool.

The science stuff

A long time ago, in a galaxy far, far away...er...in a country in Europe, early Greek philosophers studied things like electric shocks that you sometimes get from touching metal objects and the apparent attraction that some materials (such as amber[1] and hair) have for each other after you rub them together. Then around the year 1700, scientists were so interested in these occurrences that they set up a bunch of controlled experiments in which they studied what happens when various materials come in contact with one another, resulting in attractions or even sparks. To explain what was going on, these scientists made up[2] the model that the world contains positive charges and negative charges.[3] Part of this model is the fact that positive charges and negative charges like to be together, so that when we separate them, they have a tendency to jump back together. In other words, there's an **attractive force**[4] between positive and negative charges.

Armed with this simple model, we can explain what happened with the balloon and your hair. Because positive and negative charges are attracted to each other, most things in the world have an equal number of positive and negative charges. Something with an excess of positive charges attracts negative charges until the numbers are equal. As such, the normal state of the world is

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[1] Amber is a resin that is a bit like rubber or plastic. The Greek word for amber is *electron,* a bit of info that explains why we call all of this stuff electricity.

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[2] If the words "made up" bother you, allow me to explain. People invent science concepts and models, which we can refer to collectively as scientific explanations. These concepts and models are not written in stone somewhere waiting to be discovered. Of course, even though people make up these ideas, there are agreed-upon rules by which one judges scientific models. Good models have to explain all sorts of observations and even predict new observations. Good scientific explanations stick around and bad ones die away. Suffice to say that the concepts and models I use in this book have been around a while.

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[3] The names positive and negative are just names. We could just as easily call them red charges and blue charges. It turns out that the plus and minus designation is useful, though, when considering the directions of electric forces.

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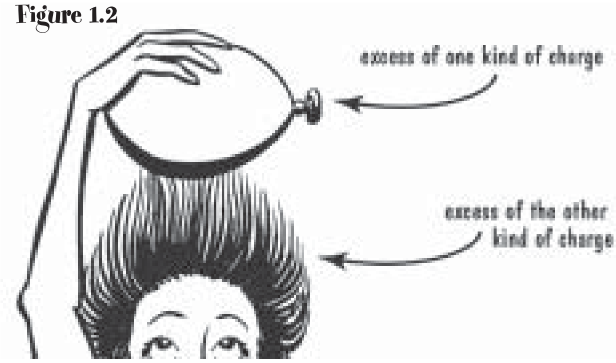
[4] *Force* is the name scientists give to any push, pull, hit, nudge, etc. For more than you ever wanted to know about forces, see the *Stop Faking It!* book on Force and Motion.

Figure 1.2



that objects are **electrically neutral** (equal numbers of positive and negative charges). Now evidently, when you rub two materials together, it's possible for either positive or negative charges to move from one material to the other, resulting in one material having an excess positive charge and the other an excess negative charge. In this situation, shown in Figure 1.2, one object (your hair, for instance) is attracted to another object (the balloon).

In addition to experiencing this attractive electric force, you also saw two charged balloons *repel* each other. Why? Well, each balloon picked up the same kind of charge (either positive or negative) when you rubbed them on your hair. Apparently this means that like charges repel. So, we have maybe the one thing you remember from studying electricity in elementary school, which is that

Opposite charges attract and like charges repel.

You also should have noticed that electric forces get stronger as the objects get closer together and weaker as the objects get farther apart. The two balloons don't push on each other appreciably until you get them close together, and the charged balloon stops pulling strongly on your hair when you get the balloon far enough away from your head. The fact that electric forces decrease with distance is really important for explaining what you'll observe in the next section. One other important fact that we shouldn't just gloss over is that once separated, the two kinds of charges tend to get back together with each other (remember, opposite charges attract) so that the overall tendency of objects is to be electrically neutral. Charged balloons don't stay charged forever.

Let's take just a minute and reflect on this simple model of electric forces. We claim that objects contain both positive and negative charges, and also that opposite charges attract one another and like charges repel one another. The forces get weaker with increased separation of the charges. We have *made up* the existence of these charges to explain our observations. Of course, we haven't yet decided whether, when you rub a balloon on your hair, the balloon gets a net positive charge or a net negative charge. That's because the choice of which charges are positive and which are negative is *totally arbitrary*! Fortunately, we don't have to stew over which to call positive and which negative, because Ben Franklin already made the arbitrary choice for us.

We can update that simple model of positive and negative charges moving around and exerting forces on one another. Currently scientists use a model stating that material consists of things called atoms. Maybe you've heard of them. An **atom** is composed of a central nucleus, which contains positively charged protons and neutral neutrons (clever name, huh?), surrounded by a rather vague cloud of negatively charged electrons.[5] See the drawing in Figure 1.3, and notice that I did not draw an atom like a solar system, with electrons in orbits around the nucleus. Turns out that model, while useful for explaining a few things, just doesn't cut it in the long run. Also, the thing keeping electrons near nuclei (plural of **nucleus**) is that simple model that opposite charges attract. Nuclei, containing positive protons, attract negative electrons.

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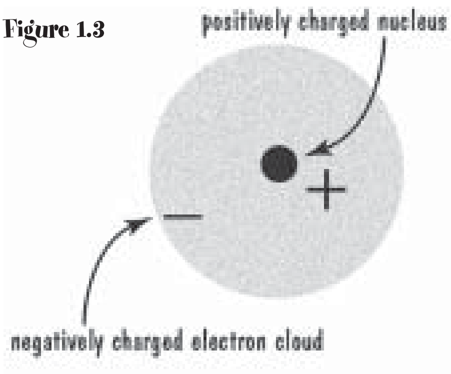
Figure 1.3



Anyway, it turns out that different materials have atoms with different numbers of **protons**, **neutrons**, and **electrons**. Also, some nuclei hang onto their electrons stronger than other nuclei. When you put different materials together, sometimes the strong-attracting nuclei steal electrons from the weaker-attracting nuclei. That makes electrons jump from one material to another. In this way, the atoms in a balloon steal electrons from the atoms in your hair.[6] That gives the balloon an excess negative charge and your hair an excess positive charge, which causes your hair to move toward the balloon.

Okay, what's going on when you rub a balloon on your head and then place it near a friend's hair? Little to no attraction, right? The secret here is that rubbing the balloon on your hair left your hair positively charged and the balloon negatively charged. Big attraction. Your friend's hair is neutral, because you didn't steal any electrons from it. Although a negatively charged object *can*

[5] The question I hope pops into your mind is, "How in the world do we know that atoms exist, and if they do, how do we know that they're composed of protons, neutrons, and electrons?" Great question, but I'm afraid I can't answer it within the scope of this book. Unfortunately, you'll just have to accept that this is a scientific model that works, and that there are lots of experiments that make atoms like these a good explanation of how the world works. Of course, atoms still are just a model. You don't have to believe in them if you don't want to!

[6] Technically, the atoms in both the balloon and your hair are part of larger things called *molecules*, and it is correct to say that the *molecules* steal electrons from each other. For now, I'll just stick with the atom description and not complicate matters. The process is the same for individual atoms or complex molecules.

attract a neutral object (see the next section), that attraction generally isn't nearly as strong as the attraction between a negatively charged object and a positively charged object.

Finally, what about shuffling your feet across a carpet and then touching something metal? Pretty simple, actually. When you shuffle your feet on the carpet, you steal electrons from the carpet. You now have an excess of electrons, and a resulting negative charge. When you get near the metal object, those excess electrons jump over to the metal (I'll explain why in the next "science stuff" section). You can see and feel the resulting spark when these electrons jump.

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Topic: Static Electricity

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Topic: Current Electricity

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We refer to the business of charges exerting forces on other charges as **static electricity**. Static means not moving, and in all the examples we talked about so far, the charges are stationary once they go from one object to another. Now it might seem silly to refer to this as static electricity when the charges do, in fact, move from one place to another. It turns out, though, that there is another phenomenon known as **current electricity**, in which the charges are in constant motion. So, when the charges are stationary for a fair amount of time, we call it static electricity.

More things to do before you read more science stuff

Still have one of those inflated balloons? If not, get another one. Tear a piece of paper into tiny bits and place them on a table. Next rub the balloon on your hair, on a carpet, or on a mellow dog. This will give the balloon excess electrons and an overall negative charge, right? Now slowly bring the charged balloon near the bits of paper. Do your best to stop before the bits of paper actually jump up to the balloon. They should do a nice little dance for you. For a change of pace, you can substitute a pile of pepper for the tiny bits of paper. You're going to do a few more fun things with balloons in this section, but before you do them, see if you can answer the following question: If the bits of paper and the pepper are electrically neutral (which they are), how come they're attracted to a negatively charged balloon?

Okay, on to more fun things. Place a Ping-Pong ball on a smooth surface. Charge up your balloon again (hair, carpet, dog) and bring it near the Ping-Pong ball without touching it. Be sure to hold the balloon slightly above and to the side of the Ping-Pong ball, as shown in Figure 1.4. I guess this means Ping-Pong balls like balloons. Repeat this using an empty aluminum pop can in place of the

Ping-Pong ball. Again hold the balloon slightly above and to the side of the can.

Get some bubble solution and blow a few bubbles. Bring the charged balloon near one of the floating bubbles, again without touching the bubble with the balloon. This proves that bubbles like balloons, too! With a little practice, you can use a charged balloon to make a bubble rise and fall repeatedly, sort of like you have a string attached to the bubble, as our magician friend is doing in Figure 1.5.

Final magic trick before you get to the Applications section. Charge up your balloon again and bring it near a thin stream of water. You should be able to deflect the stream of water to the side as long as you don't touch the stream with the balloon (Figure 1.6).

Figure 1.4

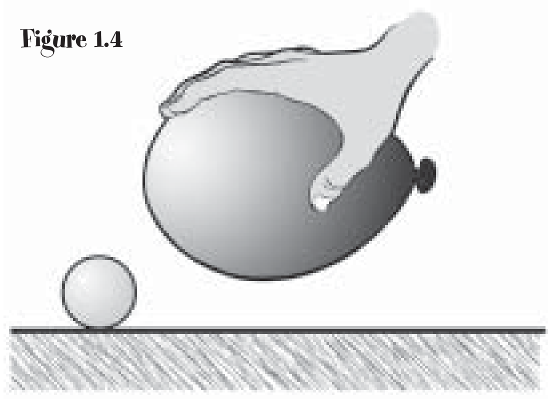


Figure 1.5

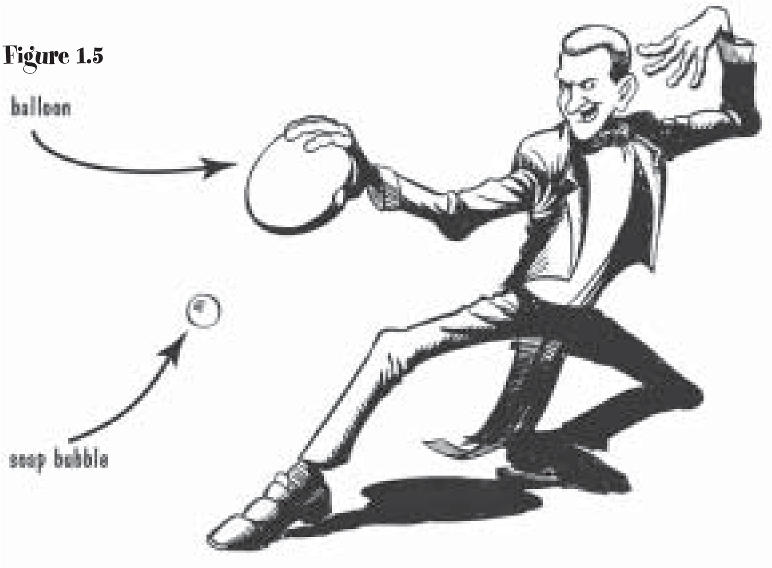
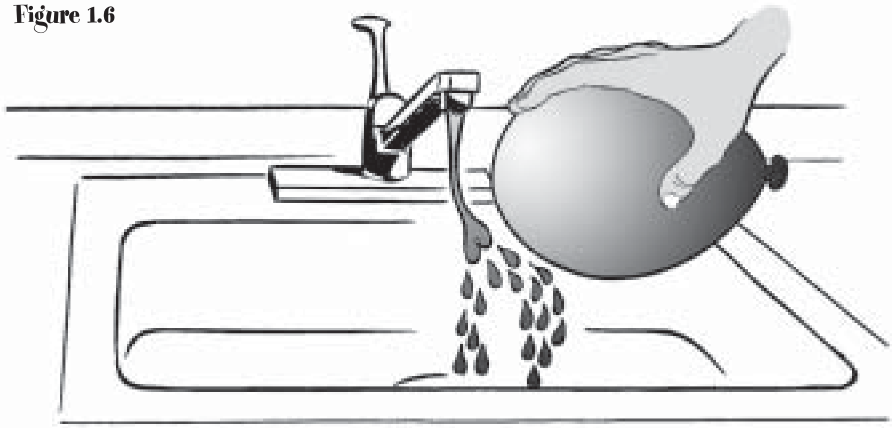


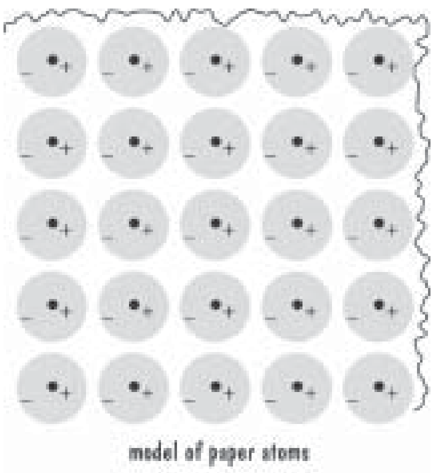
Figure 1.6



More science stuff

In every activity in the previous section, you brought a charged object (the balloon) near an uncharged, or neutral, object or substance (the paper bits, the Ping-Pong ball, the bubbles, the water, and so on). These all resulted in attractive forces. Let's see how that might happen. For starters, Figure 1.7 shows a simplified model of what the atoms in a tiny piece of paper look like. This is a simplified model because the atoms in a piece of paper are of many different kinds, and they are organized into molecules. Figure 1.7 just shows orderly rows of atoms, each with a positively charged nucleus and a negatively charged cloud of electrons around the nucleus.

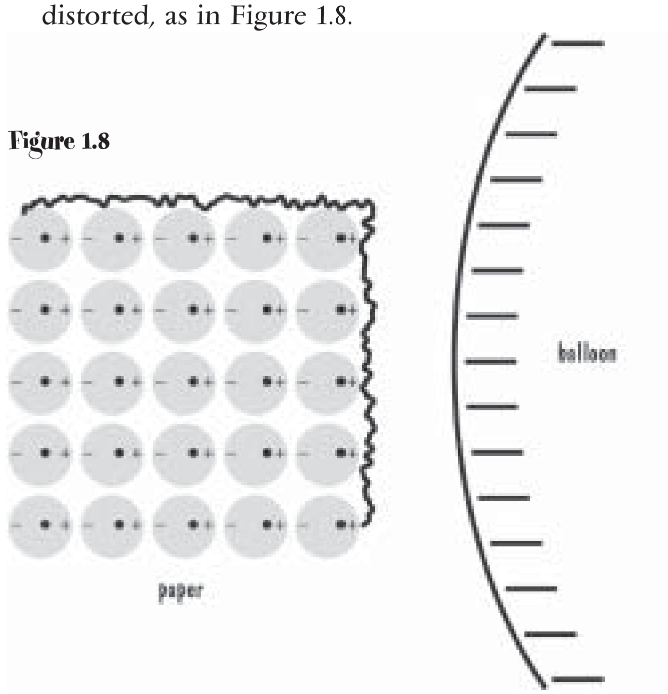
Figure 1.7



In this model, the positively charged nuclei are essentially stationary, and the **electron clouds**, while not free to move all over the place, are able to move a little bit.

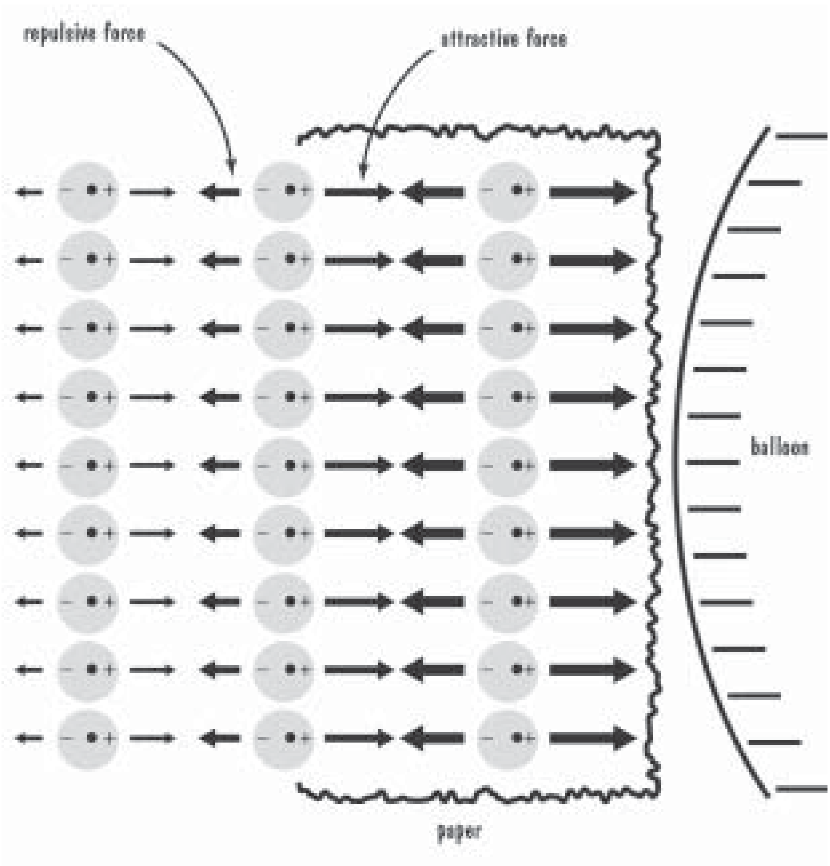
Okay, what happens when you bring a negatively charged balloon near the paper? Because like charges repel and unlike charges attract, the balloon pushes the electron clouds away and attracts the nuclei. Only the electron clouds, however, are able to move a little bit. What happens, then, is that each atom in the paper gets slightly distorted, as in Figure 1.8.

Figure 1.8



While these slight distortions don't change the overall structure of the paper, they do create a situation where, *on average*, the positively charged nuclei are closer to the balloon than the negatively charged electron clouds, as in Figure 1.9.[7] At this point, you have to recall that electric forces get weaker as distance increases. That means that, *on average*, the repulsion between the electron clouds and the balloon (like charges repel) is *weaker* than the attraction between the nuclei and the balloon (unlike charges attract).

Figure 1.9



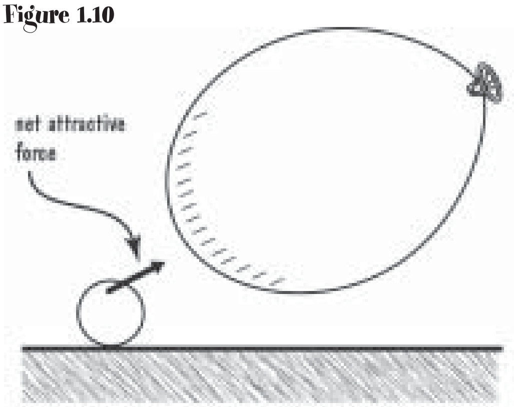
With the attraction being stronger than the repulsion, the balloon and the paper attract each other. The paper jumps up to the balloon. In this way, a charged object can attract a neutral object. Scientists say that the negatively

[7] In some resource materials and textbooks, you will read that the electrons in the paper, being pushed away from the balloon, rush to the other side of the piece of paper. That just ain't so, because the electrons in paper do not have that much freedom of movement; they can't jump from one atom to another.

charged balloon has **induced** a charge in the paper, and the paper is said to contain an **induced charge**. That term sorta makes sense, because the paper doesn't really have an overall net charge, but the presence of the balloon makes it acts like it does. Kind of like *induced labor*, which isn't naturally occurring labor but sure as heck has the same result!

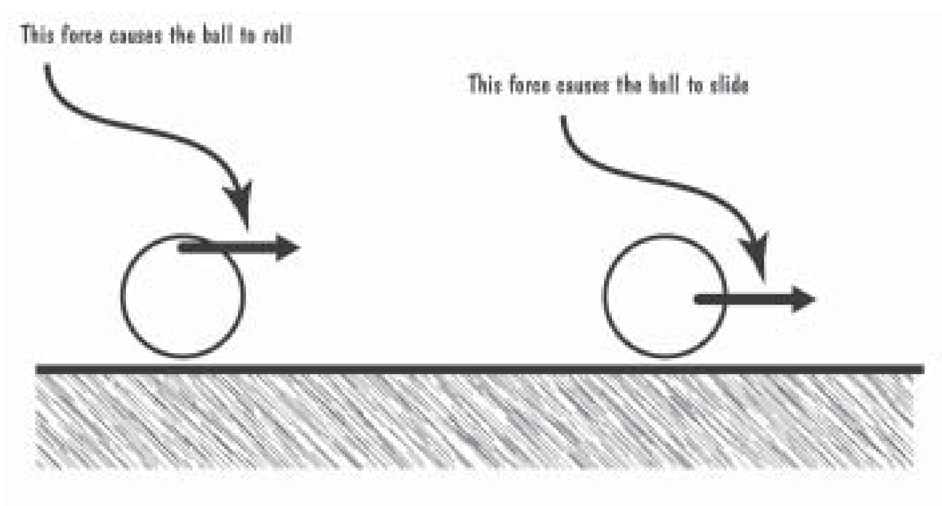
All the other things you did in the previous section rely on the balloon inducing a charge in a neutral object. The pepper is exactly like the bits of paper, except there you would talk about the atoms in the pepper instead of the atoms in the paper. The Ping-Pong ball is also just about the same procedure, but I really ought to explain the necessity of holding the balloon in the proper place in order to get the Ping-Pong ball to roll. As with the paper and the pepper, the negatively charged balloon induces a charge in the Ping-Pong ball, resulting in a net attractive force (check out Figure 1.10).

Figure 1.10



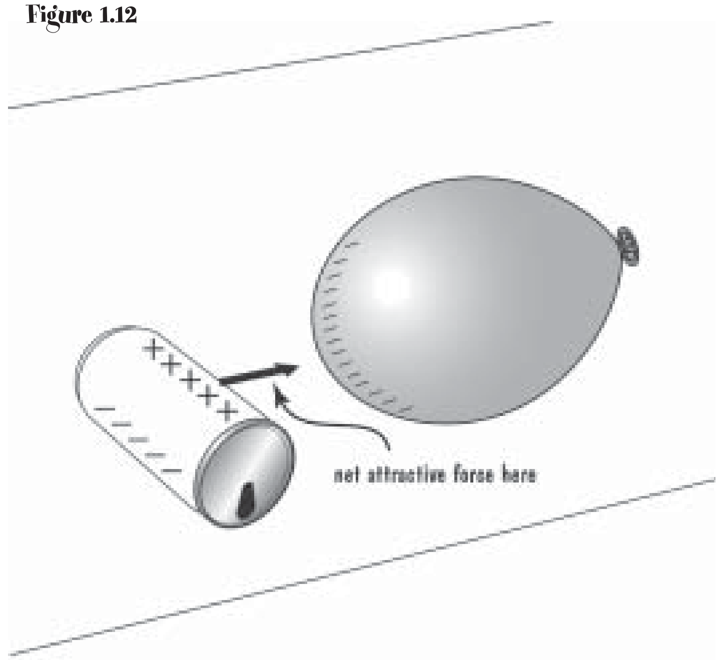
When you apply a force as shown in Figure 1.10, you will cause the ball to roll. Contrast this with what would happen if you held the balloon directly to the side of the Ping-Pong ball. In that case, you'd exert a force on the ball such that you would make it *slide* instead of roll (see Figure 1.11). It's easier to roll a Ping-Pong ball than slide it (you have to work against friction in the latter case), and the electric force between the balloon and the ball generally isn't strong enough to slide the ball.

Figure 1.11



On to the aluminum pop can. The position of the balloon again is important (you want to roll the can rather than slide it), but there is a big difference in what the atoms in the can are doing. The current scientific model for what's inside metals (aluminum is a metal!) is a bunch of positively charged nuclei that don't move around, just as with nonmetals like paper, but with electrons that are basically free to move around inside the metal.[8] Therefore, when you bring a negatively charged balloon near the metal, all the electrons in the metal tend to move away from the negative balloon (like charges repel). You end up with something like Figure 1.12.

Figure 1.12

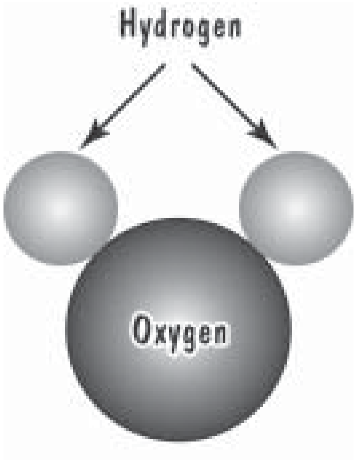


The net effect is the same. Because electric forces get weaker with distance, the attraction of the balloon to the positive side of the can is stronger than the repulsion of the balloon for the negative side of the can. The overall attraction for the can is larger than the overall attraction for the Ping-Pong ball (you'll notice that it's easier to use the balloon to roll the can than to roll the Ping-Pong ball) because the charge separation is greater when the electrons are free to move around (the metal can) than when all you can do is distort the individual atoms a bit (the Ping-Pong ball).

The last things to explain are the soap bubbles and the stream of water. They're basically the same process, so I'll just explain the stream of water. The scientific model for what's inside liquids is a bit different from that for solids. The model for solids is that the nuclei are essentially motionless (the nuclei actually move a bit, but not enough for us to worry about), and the model for liquids is a collection of molecules that kind of slip and slide over, under, and

[8] The actual accepted model for metals is somewhat more complicated than electrons just running around all over the place. Only some of the electrons in a metal are really free to roam, with mild restrictions on their motion. For our purposes here, however, we'll just stick with the picture of stationary nuclei and electrons that have a free run of the metal.

Figure 1.13



across one another. Water molecules contain one oxygen atom and two hydrogen atoms, arranged so they look just a bit like that mouse that lives in Florida and California (see Figure 1.13).

The electrons in a water molecule are shared by all three atoms, but they tend to spend more time around the oxygen atom than they do around the hydrogen atoms. This leaves one end of the molecule positively charged and the other end negatively charged. Such an arrangement, by the way, is known as an **electric dipole**, where "di-" means "two." Thus, a dipole has "two poles," one positive and one negative, shown in Figure 1.14.

Figure 1.14

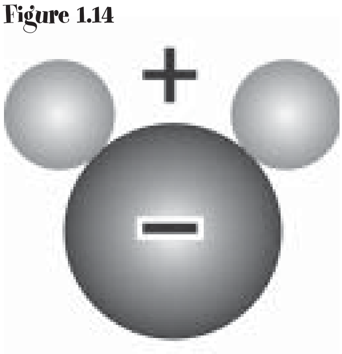
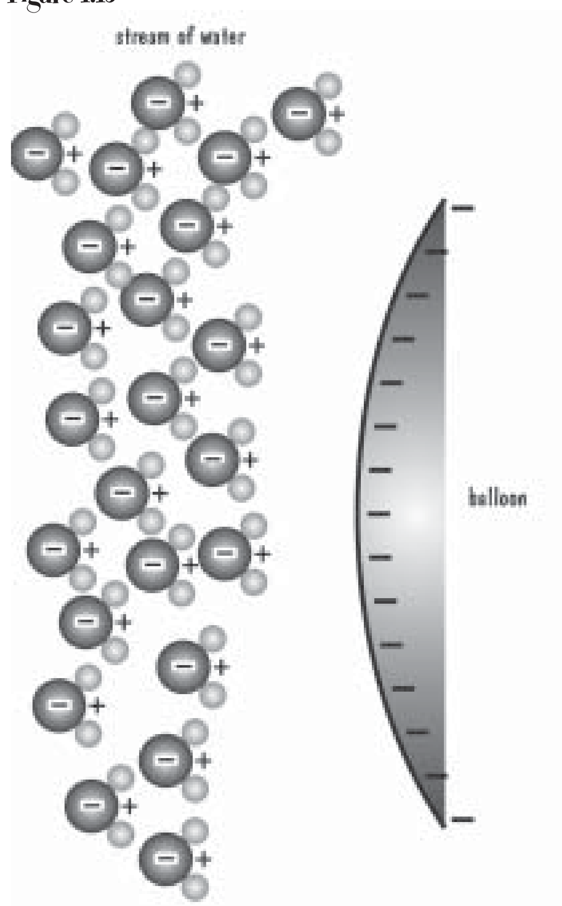


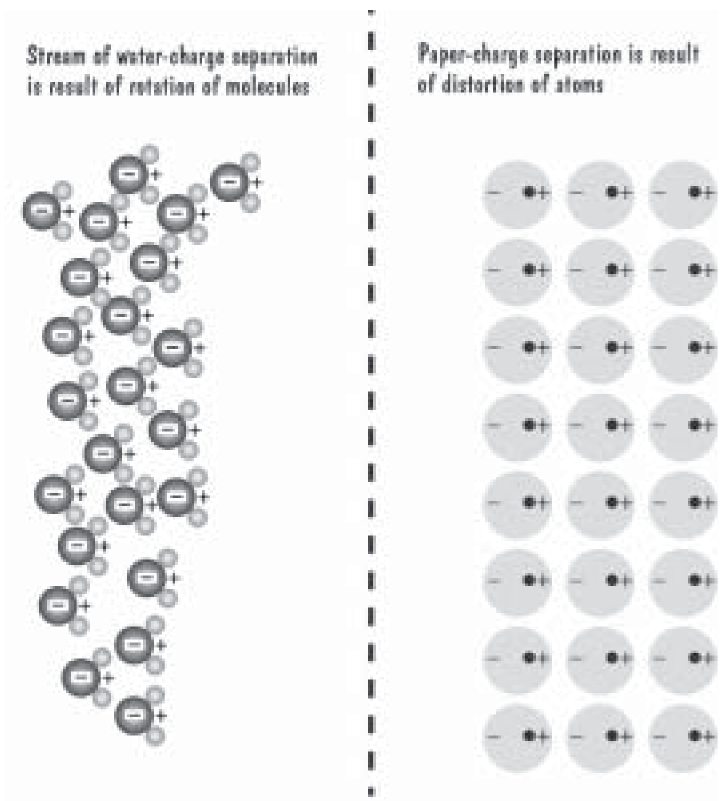
Figure 1.15



Let's look at a stream of water. It's a collection of lots and lots of these little hydrogen-oxygen dipoles. The charged balloon exerts a significant force only on the water molecules closest to it (remember, electric forces decrease with increased distance). Because the negatively charged balloon *attracts* the positive end of the water molecules and *repels* the negative end of the water molecules, the molecules closest to the balloon rotate so the oxygen end is away from the balloon and the hydrogen end is close to the balloon (see Figure 1.15).

Just as with our bits of paper, the negative charges are, *on average*, farther from the balloon than the positive charges. This results in a net attraction to the balloon, and the stream of water deflects. The difference between the water and the paper is that in one case you get a charge separation by the rotation of molecules and in the other you get a charge separation by distortion of individual atoms, as shown in Figure 1.16.

Figure 1.16



The attraction of a charged balloon for soap bubbles is just about the same as for the water, what with bubbles and water both being liquids. The only difference is that, in addition to having water molecules involved in the reorientation, bubbles have other molecules, such as soap and maybe glycerin, involved.

Oops, I lied. The water stream wasn't the last thing to explain in this section. I promised earlier that I'd explain why electrons jump from your hand to a metal object after you shuffle your feet on a carpet. Simple enough. When you bring your negatively charged finger near the metal object, the negatively charged electrons in the metal flee from that finger.[9] That leaves a positively charged region in the metal near your finger. That positive charge attracts the excess electrons you have with you to the point that they jump across. The actual jumping of electrons is an example of current electricity. More on that in later chapters.

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[9] As the Monty Python folks would say, "Run away ...... run away!"

Chapter Summary

- There are two kinds of electric charges in the world—positive and negative.
- Static electricity deals with the electric forces between stationary charges.
- Like charges repel and unlike charges attract.
- Atoms in substances are composed of negatively charged electrons surrounding a positively charged nucleus.
- Electric forces get smaller as the distance between charges increases.
- You can *induce* a charge in a substance by creating a separation between the positive and negative charges in the atoms or molecules in the substance.
- An object that is positive on one end and negative on the opposite end is called an electric dipole.
- A large number of the electrons in metals are essentially free to move throughout the metal.

Applications

1. When I was a kid, trucks carrying flammable liquids used to have a chain attached to the truck that dragged on the ground. Every once in a while, you can still see trucks dragging chains. That chain isn't a show of force, but an attempt at safety. What follows is the incorrect thinking that people used to have leading to attaching chains to trucks. When cars and trucks move along the highway, the tires tend to pick up electrons from the pavement and transfer them to the body of the car or truck. That can lead to the buildup of lots of excess electrons. Too many electrons, and you can get a big ol' spark between the vehicle and the road, similar to the spark that jumps when you touch a metal doorknob or drinking fountain. Big ol' sparks can be a really bad thing if you have a load of flammable stuff. So, the chain attached to those trucks provides a path for the excess electrons to return to the road, minimizing the chance of any sparks. Unfortunately, that's not what happens, which is why attaching chains to trucks doesn't do what it's supposed to do. Tires do indeed pick up excess electrons from the road, but they don't transfer those electrons to the body of the truck. Instead, they simply drive the electrons in the truck away from the negatively charged tires. If you have a chain attached, the negative charge on the tires actually drives electrons off the truck and onto the road, leaving the truck with an overall positive charge. This actually *increases* the chance of a spark between the truck body and the tires or between the truck body and the road. So, the next time you see a truck with a chain dragging from it, politely go up and

explain to the driver the silliness of having that chain. Okay, maybe you shouldn't do that. What you *might* do is watch carefully the next time you're in an airplane that is being refueled. The process of adding fuel can transfer excess electrons to the plane, so the people doing the fueling attach a wire from the plane to the tarmac. This wire allows the plane to remain neutral (excess electrons head to the tarmac), eliminating the chance of a spark that could cause problems.

2. Maybe as a kid you rubbed balloons on your clothes or your hair and then placed them on a wall, where they would stick. Why do they stick? Simple. The charged balloon creates an induced charge in the wall, and there's an attraction. The balloon stays charged up for a while because the excess electrons on the balloon don't readily jump over to the wall, unless the wall is made of metal, in which case this trick won't work!

3. Right about now, I'm sure you're saying to yourself, "Balloons and hair and Ping-Pong balls are fine, but what about that annoying static cling?" Again, pretty simple. All that tumbling around in a dryer causes some clothes, such as those made of nylon, to pick up extra electrons from the other clothes. These clothes stay charged up if the weather's pretty dry, and they cling to other clothes and to you by inducing charges in other substances. Of course, static cling can be a good thing. In the manufacture of plastic food wrap and in the process of removing plastic wrap from the roll, the plastic wrap picks up and retains extra electrons. When you stretch a sheet of plastic wrap over a bowl, it sticks to the sides of the bowl because the negative charge on the plastic wrap induces a charge in the bowl, leading to an electric attraction.

4. Here's a good way to amuse yourself at bedtime. I know there are other ways, but sometimes those aren't available! On a relatively dry day (not humid), turn the lights out and then lift the covers or sheet repeatedly. In between the covers you'll see a bunch of little sparks. These are nothing more than the result of electrons transferring from one cover or sheet to another and then jumping back.

5. If you live where the humidity is low, this might be the best application of science you ever read. If it's a day when you're getting shocks every time you walk a bit and then touch something, try carrying your car keys in your hand. Before you touch a doorknob or drinking fountain or whatever, hold a key out and touch the object with that. This will discharge you (rid you of excess electrons) so you don't get a shock when you then touch the object with your hand. Of course, a spark does jump between the object and the key, and electrons do eventually go from your hand to the key to the object. Why you don't get a shock when that happens has to do with the amount of surface area involved in the charge transfer, and the fact that there really

isn't much of a gap across which the electrons jump. The more surface area involved, the less the shock. Holding a key involves a lot more surface area than extending your finger toward an object. All this means that if you don't have a key, you can significantly reduce any potential shock by touching things with your fist (larger surface area) rather than your finger. And with all this advice, we really ought to contact Heloise.