Chapter 1

What is Electricity?

Among all the discoveries mankind has made, almost nothing can compare to the use of electricity. Perhaps learning how to use fire was as big an event in its day, but that day was long, long ago.

I won't bother trying to list the ways electricity contributes to all our lives; the list is endless. As I used to tell my students, "without electricity, we all go back to the farm." (Out of simple decorum I passed over an explanation of what farm life was really like before electricity revolutionized it. It wasn't pretty.)

I should add that *electricity* and *electronics* are really the same thing. We separate them for some convenience, but these are rather artificial divisions. In general, we use the word electricity for higher-powered applications and electronics for more intricate applications. However, electronic devices such as semiconductors are commonly used for very high levels of power, and electrical devices are used in very complex circuitry. In this chapter, I am using the term electricity to apply to everything elecronic as well as to power transformers and the like.

The Invisible Force

Of course, the great problem with understanding electricity is that it is invisible. We may see its effects, but we never see the electricity itself.

For ages, men saw the lightning (explosions from the skies) and even the mysterious effects of electricity's twin, magnetism. But they could never see the cause of these effects—electricity itself. And so, it remained a deep and frightening mystery for a very long time.

The truth is that even today, we do not see electricity itself. We have come to understand electricity by application of the scientific method. We have experimented, hypothesized, and verified enough times that we are now 100 percent certain of how electricity behaves.

What is certain about electricity is that an electrical current consists of electrical charges moving through a conductor. But the explanations of this certainty have changed over time. Many texts describe electrical current as a flow of electrons. I have described electricity that way, and some time-honored electrical formulas still use that terminology. But recent research indicates that it is not a flow of electrons per se, but a flow of charges, that makes an electrical current.

Not many years ago, electrical current was thought to flow from positive to negative. Texts containing the positive-to-negative theory remained into the 1970s. However, we now have much better information that indicates a negative-to-positive flow.

The interesting thing is that, on a daily basis, an explanation of what exactly electricity might be does not matter. We know with certainty how it works, and that is more than enough. A perfect understanding of what electricity is would be very nice, but it isn't necessary for making profligate use of the stuff.

Amazing Usefulness

Electricity is unique among any form of energy known to man. It can be used at supremely small or large levels. So far, we've been able to do this with no other form of energy. None of us for example, has ever seen a nuclear-powered car, much less a nuclear-powered clock radio. As impressive and as useful as nuclear technology can be at large scale, we've never been able to use it at smaller scales.

Electricity can be used at minute and finely controlled levels in the smallest microcircuitry. Billions of complex circuits are combined in one computer chip smaller than a postage stamp. At the same time, however, it can be used to power entire cities. High-voltage lines operate at hundreds of thousands of volts, and a single circuit of this type can power huge factories, or even cities. To put it into half-technical illustrative terms, a single wire can carry as much power as could be provided by 10,000 horses.

Added to the amazing range of electricity is the fact that it can be easily delivered to wherever we want it. Small, cheap copper wires are easily used to provide large amounts of power to almost any location imaginable. In fact, the wiring in your house makes the power of three horses available at every receptacle in your living room, dining room, bedroom, and so on. (And for you city folks: Horses are *really* strong.) Your home's central air conditioner is provided with more power than nine horses!

Consider this: There is a real historical reason why we use the term *horsepower*. Before electricity, people really did have to use horses for power. When electricity came in, people had to equate its power with something they were familiar with, hence horsepower. Just for fun, try imagining the actual process of using horses to provide power for the things you do every day. It's pretty entertaining.

Now, beyond just being able to use bizarrely large or small amounts of electricity, we can also do a lot of other things to it.

We can turn electricity on and off very easily. In fact, we can turn it on and off hundreds or thousands of times in one second. (Think about that horse again.)

We can change the intensity level of electricity. We can easily, cheaply, and instantly make it a lot stronger or weaker. It can be strong enough to literally blow things up or be made so mild as to be undetectable by humans, animals, or even to microbes. That, by itself, is more than amazing.

We can make electricity change directions. Moreover, we can make it change direction as slowly or as quickly as we like. We can use electricity in one direction only (called *direct current*, or *DC*), or we can make it alternate its directions, going back and forth (*alternating current*, or *AC*). And, if we want to use an alternating current, we can make it change directions with whatever *frequency* we like. If we want it to reverse 10 times a second, we can. If we want to increase the frequency of the reversals to a million times per second, we can. The really intriguing thing about this is that electricity acts differently at these different frequencies of reversal. It's astonishing, really.

There is so much to be said on this subject that deciding where to stop is a real judgment call. I will conclude by saying that there are almost innumerable tricks that we can do with electricity. We can speed it up, slow it down, make it larger, make it smaller, and change its characteristics in a dozen different ways. When we begin to combine these tricks, we find that their number increases all the more. Amazing, amazing stuff.

The Invisible Twin

At around the time of Ben Franklin's famous kite experiment, mankind was beginning to learn how to control electricity. Immeditely following these discoveries, they stumbled across something that astonished them all: Electricity and magnetism are twin phenomena.

Every time an electrical current flows through a conductor, it creates a magnetic field around that conductor. There are no exceptions, and this phenomenon cannot be eliminated. Electricity and magnetism go together, or they go not at all.

This process goes in reverse as well. Anytime you pass a conductor through a magnetic field, a current is forced through the conductor.

Electricity causes magnetism. Magnetism causes electricity. They cannot be separated.

We do have a fairly good idea of how magnetism works, in that it involves the alignment of tiny *magnetic domains* (think of these as micromagnets) in magnetic materials. (Iron is the only really useable magnetic material.) Somehow (and I will not attempt to explain this here), the passing of a current through a wire and the alignment of these magnetic domains causes the same phenomenon.

The critical thing is that electrical energy can be turned into magnetic energy, and magnetic energy can be turned into electrical energy. This can be done instantly and easily, and the characteristics of the electricity and magnetism can be modified during the process. This is truly an amazingly useful fact.

When you understand that this transformation between electricity and magnetism lies at the core of radio transmission, power transformers, and lighting, you begin (but *only* begin) to see the incredible usefulness of the invisible twins: electricity and magnetism.

Devices That Do Intelligent Work

Other energy technologies provide power. Steam engines are very strong, for example. But no other technology can do intelligent work—electricity can.

By putting together two very basic electrical devices (resistors and capacitors), we can build timers. Furthermore, these timers are 100 percent reliable, and a beginning electronics student can build timers that will react at whatever length of time he or she wants.

We have devices that turn light into electricity and electricity into light. We have others that turn alternating current into direct current, that switch things on and off with no moving parts, that allow a small current to control a large current, and that filter electronic signals, even circuits that make decisions. All of this is done easily and with 100 percent reliability.

Note that when I say "done easily," I am referring to using the truths about electronics that we now hold. Making the discoveries themselves required a lot of very hard work by a scattered group of determined geniuses and eccentric rogues.

On our end of this chain of development, we have machines that do our mathematics for us, correct our spelling, and allow us to communicate, easily and at almost no expense, with people half a globe away. How much further we will go and how fast, no one knows, but every year sees several important new developments. It will be an interesting ride to be sure. And a few of us will rise to the level of determined geniuses and eccentric rogues and make new discoveries that open half a dozen new fields of opportunity—thus doing more to improve the daily lives of men and women than any politician could ever hope to.

Summary

This chapter provided background information on electricity. Chapter 2 discusses the three basic factors affecting all electricity and electronics.

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Review Questions

1. How have we learned to predict how electricity will behave?
2. Explain, in your own words, what the text refers to as "the amazing range of electricity."
3. When we refer to the *frequency* of an electric current, what exactly do we mean?
4. Explain the connection between electricity and magnetism.
5. What is a *magnetic domain*, and in what kind of material would you find one?
6. Describe a few of the things that electrical devices can do.