

Maria and Eduardo's Electrical Adventure

CHAPTER 1



Eduardo had a problem.

"I don't get it!" he said.

"What?" asked his sister Maria.

"I'm trying to get this flashlight bulb to light," said Eduardo, "and it won't do it."

"Maybe the bulb is broken," said Maria. She came over to look.

"No," said Eduardo, "'cause it works when I put it in the flashlight. I just can't make it work with the wire."

"Oh, is that what you're trying to do?" asked Maria. "That's easy. We did it in school last year." Maria was a whole year and a month older than Eduardo and she thought she knew everything.

"Well, if you're so smart, why don't you try it?" said Eduardo. "Here's the battery and the bulb and some wire. You make it light!"

"I can do it," said Maria, "Just watch!"

CHAPTER 2

Outwardly, Maria seemed confident that she could make the bulb light, but inside she wasn't so sure. How had they done the trick in school? She remembered touching a wire to the tip of the bulb. Was that all there was to it?

"Here," she said to Eduardo. "You hold one end of the wire and I'll hold the other." She handed the battery to Eduardo. "Touch your end of the wire to one end of the battery."

"Which end should I use?" asked Eduardo.

"I don't think it matters," said Maria, a bit uncertainly, "but we'll try both, just to be sure."

She touched her end of the wire to the tip at the bottom of the bulb while Eduardo touched his end to the tip of the battery.

The bulb didn't light.

"Try touching the other end of the battery," suggested Maria. Eduardo turned the battery over and touched the wire to the flat end. The bulb stayed off.

"Maybe you're supposed to touch the glass part of the bulb," said Eduardo.

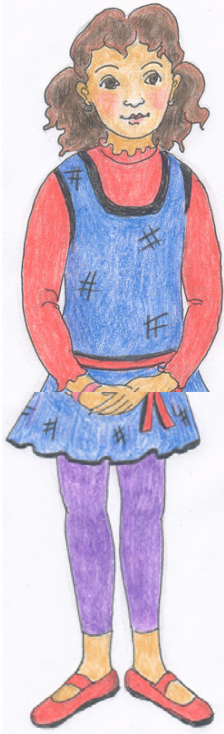
"I'm pretty sure that won't work," answered his sister, "but I'll try." She touched her wire to the top of the bulb and all around the sides, including the part where it screwed in. Nothing worked.

"You're sure the battery and the bulb are OK?" asked Maria.

"Sure," answered Eduardo, "and I can prove it. Watch!" Eduardo opened up a flashlight, put the battery and the bulb in it, and flipped the switch. The bulb lit up.

"See?" said Eduardo, "The battery and the bulb work fine in the flashlight. They're not broken. We must be doing something wrong."

CHAPTER 3



"I know!" said Maria. "The flashlight has two batteries. We are only using one. That's why the bulb isn't lighting up."

"You're right!" said Eduardo. "Let's try using two batteries." They found some tape and used it to hold the two batteries together in a line so that the flat part of one battery touched the tip of the other.

Then Maria touched one end of the wire to the bulb while Eduardo held the other hand against the tip of one of the batteries. But still the bulb didn't light up.

"I thought you said you knew how to do this," said Eduardo.

"It worked fine in school," replied Maria. "If only I could remember what we did to make it work."

"Why don't we ask Elvira?" said Eduardo. "She always knows about stuff like this."

"That's a great idea!" said Maria. "Let's call her up right now and see if she'll come over and help us."

It was a beautiful day. Maria and Eduardo played catch outside while they waited for Elvira. They could hardly wait to see what adventure she would take them on this time. Funny things happened when Elvira was around.

Pretty soon they heard the roar of the engine of Elvira's little red car. It stopped outside their house and Elvira got out, carrying a large bag made of some sort of shiny material. The bag was purple with yellow flowers and it was big enough to carry a small dog or a birthday cake, but not both together!

"So what seems to be the problem?" asked Elvira as she hugged Eduardo and Maria in turn.

"Eduardo can't make the bulb turn on!" said Maria.

"Maria said she knew how, but it didn't work," said Eduardo. "We think there might be something wrong with the wire."

"Did you look inside the battery?" asked Elvira.

"No," said Eduardo, "but we're sure the battery's OK. We tried it in the flashlight."

"You know it works, but you don't know *how* it works," said Elvira, mysteriously. "How can you fix something if you don't know how it works?"

"But how can you look inside the battery?" asked Maria.

"I'll show you," said Elvira.

CHAPTER 4

As soon as Elvira saw the way Eduardo and Maria were trying to light the bulb she said, "Ah... I think I see the problem!"

"What is it?" asked Eduardo, "What's wrong with our wire?"

"There's nothing wrong with your wire," said Elvira. "I'll show you the problem, but first we have to take a little trip."

"What kind of trip?" asked Maria. She was excited, but she was also a little scared. You never knew where you were going to end up on one of Elvira's "little trips."

"We're going to go inside the battery," said Elvira, "to see how it works."

Elvira fished in her purple bag and brought something out.

"That looks just like a magnifying glass," said Maria.

"It's sort of like a magnifying glass," said Elvira, "but it's a very special one. It can magnify things a lot more than an ordinary magnifying glass and it can look inside things. It's kind of a cross between a magnifying glass and an X-ray machine. And it does more than just show you stuff, it lets you go places. We're going to use it to go inside the battery."

She put her hand back into her bag and it came out with two headsets. They looked just like bicycle helmets except that they had built-in goggles that went over your eyes. Elvira connected the headsets to the magnifying glass with a long cable.

Then she helped Eduardo and Maria to put them on. She picked up the battery and turned it so that the flat end with the "minus" sign was close to the magnifying glass.

"I get it," said Maria. "We won't actually be going anywhere, right? We'll just see stuff." She was quite relieved. How dangerous could this trip be if they didn't actually go anywhere?

"That's right," said Elvira, "but those headsets are very realistic. It will seem to you that you're so small you can get inside things. Watch!"



She turned a knob on the magnifying glass and the battery got bigger and bigger until they couldn't see its edges any more. Then everything turned grey and they couldn't see very much at all. It was as though they were floating in a giant grey fog.

Finally, just as Eduardo and Maria were getting bored, they started to see something. It looked as if they were floating above a beach looking down at hundreds of little white pebbles. As they got closer they could see that the pebbles were little white dots, neatly arranged in rows and columns like the tiles on a bathroom floor.

"Those are copper atoms," said Elvira. "The metal part of the battery is made of copper."

"Why are they white?" asked Eduardo.

"That's just the color that the magnifying glass makes them so you can see them," answered Elvira. "They're really too small to have a color."

The dots got bigger and bigger and Eduardo and Maria could see that they were more like clouds than dots. They looked just like clouds in the sky, in fact, except that they were all exactly the same and were arranged in perfectly straight rows.

"Let's go inside the copper!" said Elvira. Maria wasn't sure that was such a good idea, but before she could object she felt that they were moving into the sea of white copper atom clouds.

"We'll steer between them," said Elvira. "Isn't this fun!"

Eduardo and Maria had never seen anything like it. Everywhere they looked, up and down, right and left, forward and back, there were those little white clouds all lined up in neat rows. "We're inside the negative tip of the battery now," said Elvira. "That's the flat end. There are electrons here but you can't see them yet."

"Why not?" asked Maria.

"Because they're too small to be seen at this magnification. But that's easily fixed." Elvira turned the knob on the magnifying glass and the atoms started to grow. Pretty soon they were so big that they didn't look like clouds any more – instead, wherever you looked you just saw white. It was like the difference between looking at the sky on a sunny day with a just a few clouds, and the way it looks on a cloudy day when the sky is white all over.

"Now if I can just slow things down a little," said Elvira, "we'll be able to see the electrons go by. There we go. Now look carefully and tell me what you see."

Maria and Eduardo stared around cautiously. For a while they saw nothing strange until all of sudden Eduardo said, "What was that?"

Something had gone whizzing past them, too fast to really see.

"I guess I didn't slow things down enough," said Elvira, "Wait a minute."

She fiddled some more with her magnifying glass and all of sudden Maria and Eduardo could see that they were surrounded by small blue objects moving this way and that.

"Those are the electrons," said Elvira, pointing at the blue objects.

"What if one of them hits us?" asked Maria, anxiously.

"They can't hit us," answered Elvira, "because we aren't really there. The magnifying glass is just showing us what it would be like if we were there. They're not really blue, either – the magnifying glass just colored them blue so you could see them."

"So," said Eduardo, "is this what an electric current looks like?"

"Not quite," said Elvira, with a little smile, "but you're close. Remember, this battery isn't attached to anything yet. Watch what happens when I go back outside and attach a wire to the battery."

CHAPTER 5

"OK, now pay attention," said Elvira. Her voice sounded faint, as though she were far away. "I'm back outside the battery now. I'm going to attach one end of the wire to the negative end of the battery, the flat end where you are. Watch the electrons and tell me if you see a difference."

"They're beginning to move away," said Maria. "I think they're going down the wire."

"Now they're all gone," said Eduardo. "Where did they go?"

"I'll show you," said Elvira. Her voice sounded perfectly normal now, "But to do that we'll have to take another little trip."

"Where are we going?" asked Maria.

"We're going to find those electrons!" said Elvira. "First let's get a little bigger! There's nothing to see any more at this magnification." She twisted the dial and the copper atoms got small until they looked like pebbles again. Then the atoms started to move.

"What's happening?" asked Maria.

"We're in the wire now," replied Elvira. "We're moving down it, from one end to the other. It's a long journey, so I'd better speed things up a bit!"

Eduardo and Maria felt that they were moving faster and faster. The rows of atoms became a blur and then disappeared completely. After a few minutes they heard Elvira say, "We're almost there!" and they slowed down again. Finally they stopped between two atoms.

"Let's magnify these atoms and see if we can find those electrons," said Elvira. The atoms got bigger and bigger, just as before.

All of sudden Maria said, "I see them now!" Sure enough there were hundreds of electrons buzzing around in all directions.

"Where are we now," asked Eduardo.

"We're at the end of the wire," said Elvira.

"So that's where all the electrons went!" said Eduardo.

"Exactly!" said Elvira. "The battery pushed the electrons down the wire just the way you could push a pea through a straw by blowing on it."

Maria had a thought. "Wait a minute!" she said, "There's something wrong here. If I blew a pea through a straw it would come flying out the other end. How come the electrons are stuck like this at the end of the wire?"

"That's the whole point!" said Elvira. "That's why the bulb didn't light up for you. The electrons can't leave the wire. They're trapped in it so they all pile up at the end."

"I don't see what that has to do with the bulb not lighting up," said Eduardo.

"Neither do I," said Maria.

"Just wait here and I'll go attach the end of the wire to the tip of the bulb," said Elvira, "just the way you did. What do you think will happen?"

"I don't know," said Maria.

"Neither do I," said Eduardo.

CHAPTER 6

Elvira went off to attach the bulb to one end of the wire, leaving the other end attached to the battery.

"The electrons disappeared again!" called Eduardo.

"OK, let's go find them," said Elvira.

They started to move again. "We're in the little knob at the bottom of the bulb," said Elvira, "It's connected to the filament."

"What's the filament?" asked Eduardo.

"It's the part that lights up," said Maria. "We learned that in school."

"Right," said Elvira, "The filament is a very thin wire. We're getting to it now. Let's stop for a bit and look around. First I'll zoom out so you can see the whole thing."

The filament was indeed very thin. It looked as though it might break any minute.

"It's thinner than one of your hairs," said Elvira. "When electrons run through it they heat it up until it is the temperature of the sun!"

"Wow!" said Eduardo, "Why doesn't it burn up?"

"That's why it's got all that glass around it," said Maria. "They take out all the air and put in special gases so it can't burn."

"Did you learn that in school too?" asked Eduardo. He was getting annoyed with Maria for being such a know-it-all.

"Let's go see what it looks like inside the filament," said Elvira.

From the inside the filament looked pretty much like the battery and the wire, except that the atoms were brown instead of white. Elvira said that they were tungsten instead of copper, so the magnifying glass colored them differently. "Copper would melt," she explained.

"I still don't see the electrons," said Maria. "They must not be in the filament."

"OK, let's move on then," said Eduardo.

They moved through the filament and out the other side. "Now we're in the base of the bulb," said Elvira, "the part that you screw into the socket. This is the end of the line. There's nowhere else for the electrons to go."

Sure enough, there were electrons zooming all around.

"They got stuck again," said Maria, "They can't go anywhere."

"And that's why the bulb isn't lighting up!" said Eduardo, excitedly. "There's no current through it. The electrons are blocked."

"So now do you know what to do to get it to light?" asked Elmira.

"Sure we do!" said Eduardo and Maria.

CHAPTER 7

"All we have to do," explained Eduardo, "is attach the screw part of bulb to the other end of the battery – the end with the little knob."

"Yes, that will work," said Maria. "That way the electrons will have somewhere to go."

"You're both right," said Elvira. "To get a current you have to make a complete path for the electrons to go from one end of the battery to the other. The electrons go from the negative end of the battery, which is flat, to the positive end – the one with the knob. Let's get out of here and try it!"

A few minutes later Eduardo and Maria were looking at a light bulb shining away with two wires leading from it to the opposite ends of the battery.

"Now I remember that we used two wires in school," said Maria, "but I never understood why. I guess that's why I forgot!"

"There's still something I don't understand," said Eduardo. "Why don't the electrons just pile up when they get to the battery, same as they do at the end of the wire? What goes on in that battery, anyway?"

"There's only one way to find out," said Elvira. "Let's go back inside the battery and take a look at the positive end." She disconnected the wire from the positive end of the battery. Immediately, the bulb went out. Then put the special magnifying glass close to the positive end of the battery. Eduardo and Maria put on the headsets and got ready for their trip into the battery. In no time they were staring down at the white copper atoms on the plus side of the battery. Maria noticed a difference.

"How come some of the atoms are colored red?" she asked.

"Those are called 'ions'," said Elvira. "They're atoms that have lost one electron. Electrons have a negative charge, but these ions have a positive charge."

"And positive charges attract negative charges, right?" asked Maria. "I remember that from school."

"Right," said Elvira. "So what do you think will happen if I connect this side of the battery to the wire again?"

"Hmm, let's see," said Eduardo. "The electrons are all stuck on the end of the wire, right? So when you connect it to the battery they're all going to come roaring in here and..."

"And they'll be attracted to the red ions!" said Maria. "But then I don't know what will happen. Will there be an explosion?" she asked, a little fearfully.

"No," said Elvira, "I promise you there won't be an explosion. Just the last step in completing the circuit. Are you ready?"

"I guess so," said Maria.

"OK, here goes." Elvira connected the wire to the battery. "What do you see?"

"Some of the red ions are turning white," said Eduardo.

"And some of the white atoms are turning red," said Maria. "What's going on?"

"Let's turn the magnification up," said Elvira, "so you can see the electrons. There."

"Now I get it," said Eduardo. "An electron comes along and bumps into an ion."

"It's attracted to the ion!" Maria interrupted excitedly.

"Yeah, it's attracted to it," said Eduardo, "And then it kind of gets swallowed up by it and the ion turns white."

"Right," said Elvira. "The red color is just a way to show positive charge. So a negative electron is combining with a positive ion to make a neutral atom, which doesn't have a charge. We color the neutral atoms white."

"So when a white atom turns red, what's happening?" asked Maria.

"Look closely," said Elvira. "What do you see?"

"OK I see it now," said Maria. "Whenever a white atom turns red a blue electron always comes out of it. The neutral atom loses an electron and becomes a positive ion."

"So that's what the battery does," said Eduardo, "it takes electrons away from the atoms on the positive side and pushes them onto the negative side. Then we connect the two sides and electrons move through the wire back to the ions."

"And when the electrons go through the filament in the bulb they heat it up and it glows and that's how we get light," added Maria. "It all makes sense."