But Why: A Podcast for Curious Kids

How Do Circuits Work?

July 19, 2019

[Jane] This is *But Why: A Podcast for Curious Kids* from Vermont Public Radio. I'm Jane Lindholm. On this podcast, we take questions from curious kids just like you from all over the world and we find answers. We recently took some of your questions live on the radio, on Vermont Public Radio, in fact. And today, we're listening back to the second half of that program. If you missed our previous episode, you can go back and listen to that first to get some of the basics of what electricity is and how it works. We're answering your questions about electricity with electrical engineer, Paul Hines. He's a professor at the University of Vermont and the co-founder of a company that deals with electricity. Before we get back to the program, we want to answer a question that didn't get on to the radio the day we recorded with Paul. It's from Felix.

[Felix] …and I am 6 years old. I live in Manchester, Massachusetts. Why do some things conduct electricity and why do some things not conduct electricity?

[Jane] Everything is made of atoms. Atoms are a kind of ball with lots of little balls on the outside. Those balls on the outside are called electrons. Now some atoms have surplus or extra electrons. Atoms like copper and aluminum have extra electrons that jump from one atom to another. They can share their electrons with their neighbors. That makes them good conductors of electricity. Things like water and glass want to hold onto their electrons. They don't want to share, so their electrons don't want to jump around as much, so they, in turn, don't conduct electricity as well. Thanks for the question, Felix. Now, we're gonna just dive back into the show with a question about batteries. Let's go to Hazel, who's calling in from Bayfield, Wisconsin. Hi, Hazel.

[Hazel] Hi, I'm 7 years old, and my question is, “How do they get the electricity to charge ipads?”.

[Jane] Hazel, great question. Before we get an answer, we're going to go to Rosalie in Denver, Colorado. Hi, Rosalie.

[Rosalie] My name is Rosalie, I’m five years old and my question is, “How does electric power devices like tablets and phones?”.

[Jane] Rosalie, good question. You and Hazel have a great question there and we're going to pair it with this question that we have on tape.

[Grace] Hi, But Why. I'm Grace. I'm 10 years old and live in Medford, Oregon. My question is, “How, when you plug in a phone with a battery, how does it charge your phone?”. Thank you.

[Jane] OK. So, Paul, what all of these kids are asking about is how does electricity charge something that doesn't necessarily have a plug attached to it? So our tablets, we charge them up, but then we can take them somewhere. Same with our phones, same with some other things. And same with things that use batteries. They're running on power, but it's not plugged in. It's not traveling in that way that you talked about with wires.

[Paul] So I've actually got some batteries here. So all of these things, iPads and phones and even like a portable TV, all these things run on batteries. So your laptop computer, for example….and so I've got a couple of batteries here and I've got a little circuit that creates some sound. [twizzly sound in background] You can kind of hear it there. And so what's happening, when you charge the batteries, is that, you know, a lot of batteries that you use are made out of an atom called lithium. And lithium has an extra electron in it. And so what happens with that electron, that extra electron, is it actually can move back and forth really easy. It can grab an extra one if it needs to or can lose its electron without too much trouble. And as a result, it's a good way to store electricity. And so you can basically add some electrons to it or take some electrons away. And so batteries are…. what will happen is that you take the electricity from the wall socket and it stores it up in that battery so that it can be used later. And I can do things like turn on my little speaker. [twizzly noise again]

[Jane] Well, OK. So, you used a word that I'm going to have to help you explain or have you help explain to us. So here's a question from Sammy, who lives in Manchester, Vermont.

[Sammy] My question is “How do circuits work?”.

[Jane] You said, “I have a circuit and I'm going to, you know, turn it on and I'm gonna get this sound to play”. But what is a circuit?

[Paul] So a circuit is just… it comes from the same word that we use for circle. So a circuit is just a circle of electricity. And electricity will only flow if there's a circle of some sort. And so, you know, even the electricity in lightning, when it moves over the earth, it builds up the electricity from the earth, and then it comes back down to the earth. It's going around in a circle. And so your battery is a part of a circle. And you can only get the electricity

out of the battery if you connect it in a little circle. And so in my circuit here, I've got the batteries connected through a switch and then through a speaker and back to the batteries. And so it's only when that circuit is closed, when I close the switch, that the electricity can flow. So a circuit just means circle.

[Jane] OK. So a circuit means circle, but it has to be closed in order for the electricity to flow and to do something like turn on.

[Paul] Yup, if I break it, if I open it up, I take a part out, it won't flow.

[Jane] Alright. So I have three related questions for you here. So here's the first.

[Ivan] Hi, my name is Ivan. I live in Farmington, Connecticut. How do electric plugs work?

[Jane] All right. So electric plugs. But then here's a question from Max.

[Max] My name is Max and I'm 3 years old and I'm from Georgia and my question is "How do lights come on when somebody flips the switch?".

[Jane] And then here's one from Abigail.

[Abigail] I live in St. Louis, Missouri and I'm eight years old. My question is, "I know you need electrons to make electricity but where do the electrons come from when the electricity is on and where do they go when it's off? Do they stop in the cord or do they keep going?".

[Jane] So I played all of those together because you were talking about a circuit and you need the circle to be connected for the electricity to move and to power something. So we have that question about, you know, how do electric plugs work and then how do you actually… because sometimes you might have a lamp plugged in, but the light's not on until you turn on the switch or turn it off. And then where's that electricity going once you unplug or turn the switch off?

[Paul] That goes back to the idea that electricity is everywhere all the time, it's just that we can't make any good use of it until we make a circuit, till we make it into a circle. And so with the plugs, for example, when you plug a fan in in your house, you plug it in and you turn it on, that closes that circuit. And so the electricity comes in one side and goes out the other side. And so the plug is just a way to make a circle or a circuit. The light switch is pretty much the same. And so the light switch is a little lever that you can turn on and off. And so when I turn the lever on, it makes the circle, it closes the circuit and the electricity flows through the light bulb. When I turn the light switch off, it opens

the circuit, and so now all the electricity is stuck. Now, the electricity didn't actually disappear, it's still there. It's still stored up in those wires. There's still electricity in those wires. It just can't move anywhere. It's stuck.

[Jane] So is it building up behind the wire, but it doesn't explode when we when we plug something in or turn something on?

[Paul] No, we've designed the system to be really safe so that it would only… you know, it is true, if you get two wires really, really close together, they'll jump. And so that's dangerous. So you want to make sure you work safely with electricity. But the system is designed really well. So we keep the the electricity apart so that it doesn't jump or explode.

[Jane] Let's go to Gwendolyn, who's calling in from Quechee, Vermont. Hi, Gwendolyn. How old are you?

Hi, Gwendolyn, do you hear me? Are you there? All right, so we don't have Gwendolyn. We're gonna take a quick break.

We're listening to this special live hour of *But Why*, it's VPR's podcast for curious kids. And we're tackling a really complicated, well, I think it's complicated, subject today. Maybe all of this makes total sense to you, but I find it fascinating. We're talking with Paul Hines. He's an electrical engineer and he's helping us understand electricity.

[Jane] This is *But Why*, a podcast for curious kids. I'm Jane Lindholm. And today, we're doing a special live version of our VPR podcast. We are tackling just some of the more than 80 questions we've gotten about electricity and we're getting more and more as the show goes on. I find electricity fascinating and we're talking with somebody who really knows this stuff backwards and forwards. His name is Paul Hines and he's what's called an electrical engineer. He teaches this kind of stuff to students at the University of Vermont. And he also has his own company where he's trying to solve some of the challenges that we've been talking about…about getting electricity to all the devices we use in the most efficient way possible. So we were trying to talk to Gwendolyn from Quechee, Vermont and I think we have her back on the line. Hi, Gwendolyn, are you there?

[Gwendolyn] Yes.

[Jane] Oh, excellent! What's your question?

[Gwendolyn] My question is, "How do the streetlights turn on?".

[Jane] Good question. Paul Hines, how do streetlights turn on?

[Paul] Streetlights are really very similar to the lights you have in your house. There's a switch and the switch turns on. Now, some of those street lights are actually kind of smart. So they are smart enough to figure out that we only need the street lights on when it's dark out. And so what the utility will do is, they'll actually put a little sensor on there that measures the amount of light. And so when it gets dark out, the streetlight will basically throw a little switch automatically and make a circuit or a circle and the electricity will flow through those light bulbs and turn the lights on.

[Jane] Cool. All right, so it seems like when we need electricity, what we've been learning is, it's there. It's already there for us where our houses are wired, our tablets have plugs or they have batteries, but it's really fast. Here are a couple questions about speed.

[Nathan] My name is Nathan. I am six years old and I live in Riverview, Florida.

[Lucas] My name is Lucas. I am Nathan's twin brother, and my question is "How could electricity go faster than a man could run?".

[Rowan] Hello, my name is Rowan, I live in Carmel, Texas and I'm 6 1/2 years old. And my question is, "Why does electricity move super-uper fast?".

[Jane] All right. So we had twins asking about how fast electricity goes and Rowan asking about how fast electricity can move.

[Paul] That's a really great question. So electricity is amazingly fast. Electricity moves almost at the speed of light. And light can move so fast that it can get like from here all the way to the sun in, like, eight minutes. So incredibly fast. And so electricity does that basically by waves and all sorts of stuff. Honestly, I don't know all the details of how it works. It just moves incredibly fast.

[Jane] Is it faster than the speed of light?

[Paul] It is a little bit slower than the speed of light.

[Jane] OK. All right. So at least we've got that. Let's go to Flora, who's calling in from Los Angeles, California. Hey, Flora.

[Flora] Hi.

[Jane] What's your question?

[Flora] So I have two questions. One is, “How was solar power invented?” and the second one is “Where does the power for electric cars come from and how do they charge?”.

[Jane] Flora, thanks for those awesome questions. So, the first one is “How did we figure out solar power?”.

[Paul] Yeah, solar power is pretty cool. So we've actually known that solar power is useful since the beginning of time. And so people realized that they can put stuff out in the sun and it heats up since the very, very beginning of people. And so solars have always been useful. It was actually the solar panel that you see on people's homes and in the fields and it was invented about 100 years ago. And we realized that if electricity hits certain types of materials, the electrons start to move. And it's kind of like the opposite of a light bulb. So a light bulb, you know, when electricity moves, it produces light. We basically figured out how to turn that process in reverse. And so the light hits this certain type of material and the electricity moves. And so solar panels are basically lots of little substances that are made so that the electricity will start to move if the light hits them.

[Jane] Now, when we have solar panels on people's houses, those are sort of like small electrical generation plants. And then they have to move maybe through the wires, either to the house or to a bigger plant where they get distributed to other houses and other people's places? Is that right?

[Paul] Yeah. Most solar plants are actually connected into the grid. And so if you have solar panels on your roof, they're making electricity and putting it into the grid in the same way that, you know, giant solar fields that take up miles across and that are increasing, so they're all the same thing. That's all going into this grid. Some of that electricity will get used in their house. But some of it will actually go onto the main grid and be used by everybody.

[Jane] So, Flora's other question was about electric vehicles, but we have other questions to pair with that. Here they are.

[Child] I’m five years old and I live in El Paso, Texas. My question is, “Why do so many cars use gas and not electricity?”

[Zack] My name is Zack. I'm four years old. I live in Santa Clara, California. My question is, “Why do people have electric cars?”.

[Jane] All right. So… electric cars. Some people have them, some people don't. We're seeing more of them now. What's the deal? And how do they get their power?

[Paul] So, first of all, electric cars are really cool. And people actually have been knowing how to make electric cars for almost 100 years, almost the beginning of the car, because we knew how to make motors that use electricity to move. The thing is that we'd just discovered oil, that was a pretty good way to store energy in large quantities, and so in order to then use it for a car, you need to use a combustion engine. So you could burn the oil and then turn that into motion. Electric cars use batteries to store the electricity. You know, just like the batteries I've got in my little circuit here. And those were more expensive than using oil in the combustion engines for a long time. So, it's only just in the last few years that electric cars have become cheap enough and affordable enough that lots of people can afford them. I'm actually really excited about electric cars because now they're affordable and it actually can be a more affordable way to drive. And it's cleaner. They don't burn lots of nasty fuel and put it into the air.

[Jane] Yeah, can you talk just briefly about that? Sometimes we do hear things like "dirty power" or "clean power".

[Paul] Sure.

[Jane] What's the difference?

[Paul] So power, I mean electricity is amazing because it can basically be produced by almost anything, lots of different ways that we can produce power. Some of those are cleaner than others. And so wind and solar electricity are a great way to produce electricity because when you produce it, you don't actually burn anything that goes into the air.

[Jane] So when you say "clean", you just mean it's not putting dirty chemicals into the air as much.

[Paul] Yeah. Exactly.

[Jane] Okay.

[Paul] You know, we have to do stuff to make every type of electricity. There's always work. And some of that work is is harmful to the environment. So we always have to be careful about how we make our electricity. But wind and solar are particularly good ways that we can make electricity and it's not particularly harmful to the environment.

[Jane] And when we say "renewable energy", that's because wind just keeps coming. We're not going to use it up and have no more wind. Or sunlight, we're not going to use it up and have no more sun. So that's what it means to be renewable? It keeps coming back?

[Paul] Exactly. So wind and solar and hydro, these are renewable forms because the earth makes it all the time.

[Jane] Let’s go to Sam, who's been waiting on the line from Indianapolis, Indiana. Hi, Sam. Thanks for waiting.

[Sam] Hi, my name is Sam. And my question is “How can tiny electrons make a whole building work?”

[Jane] Sam, thanks for that question. I mean, it is amazing, Paul Hines, when you think about, you know, tiny electrons or even like tiny little devices that then light up a whole building. And sometimes these buildings are enormous. How in the world does that happen?

[Paul] It is really, really amazing. And it's just because there are so many electrons. I mean, there are millions of electrons even in the tiniest speck of dust. And so when you get, you know, a giant hydro plant producing electricity, it's just moving an unfathomable number, like gazillions of electrons are moving around. And because of that, you know, gazillions of electrons are moving through a building. And as a result, the building is able to light up. You're able to light up the building. You're able to heat it and cool it and charge the cars that are connected. And so it's just because we're moving, you know, gazillions of electrons.

[Jane] All right. Okay. So we haven't talked about light bulbs. And I want to talk about light bulbs. Here's a question first from Mack.

[Mack] How do light bulbs light up?

[Seth] Hi, my name is Seth.

[Mika] My name is Mika. I'm seven years old.

[Zander] I’m Zander. I'm six years and I live in Mountainview, California. How is light made from light bulbs?

[Kayley] Hello, my name is Kayley.

[Ozzie] My name is Ozzie, I'm five years old. I’m from Franklin, Wisconsin, [00:18:49] and my question is, “How are light bulbs made?”.

[Child] I’m from Kennesaw, Georgia and my question is, “How do lightbulbs work and how do they get so hot?”.

[Jane] We also had a question from Zack in Cranbrook, British Columbia, who also wants to know how electricity lights up light bulbs. I mean, light bulbs are pretty cool technology.

[Paul] Light is amazing. And we've been trying to figure out, you know, humans have been trying to figure out how to make light since the beginning of time. But we discovered the light bulbs about almost 200 years ago. And the way that old light bulbs are made is that you basically had a piece of paper or a piece of metal…a little teeny tiny, thin string of paper and metal…and you ran electricity through it. And then that would grow, you know, get really, really hot. And when things are hot, they produce light. So just like when you've got a fire in your camp, fire, that fire produces light. And so, you know, the older style light bulbs are basically putting electricity through a little strip of something. And then they put it in a vacuum where they get rid of all the oxygen so it doesn't burn up. And then that's a light bulb. Now, newer light bulbs do things more creatively. New LED. light bulbs are very efficient. They don't produce as much heat, which is great because you're not wasting electricity producing all that heat. And so they just turn the electricity directly into light by moving the electrons around in really careful ways.

[Jane] So before we leave this topic, and I'm sorry we didn't get to all of our questions today, but there is one more piece of this that I want to make sure we talk about, and that's safety. So here are a couple of questions about that.

[Wyatt] My name is Wyatt and I'm four years old and I live in Connecticut.

[Cohen] Hi, my name is Cohen and I'm from Dayton, Ohio. I'm eight years old and I'd like to know why electricity is dangerous.

[Lily] My name is Lily, I live in Heyworth, Illinois, and I'm six years old. My question is, "How can electricity kill you?".

[Jane] We also heard from Collette, who's five and lives in Medford, Oregon, wondering why it hurts when you get shocked by electricity. But Paul, I just want to make sure we don't leave without saying that you need to be careful around electricity.

[Paul] Absolutely. You should really, really be careful around electricity. Electricity is dangerous for the same reason that driving in a car is dangerous. You're moving really, really fast. And so when you move fast in a car, if you smash into something, that's going to hurt people. And electricity is moving a lot of energy in the same way a car is moving a lot of energy. And so if you touch it, it's going to move really fast through your body. It can burn you or even do worse things. And so, it's basically that flow of electricity.

Now, one way that it can hurt is if it actually flows through your heart, it would stop the electrical signals that run your body. And that's really dangerous because that can actually kill you.

[Jane] So don't touch power lines, don't touch plugs. Don't go out in a lightning storm and just be careful and talk to your adults. I want to give a great big thanks to our guest for today, Paul Hines. Paul, thank you so much for explaining electricity to us.

[Paul] This is really fun. And thanks to the kids for great questions.

[Jane] They really did have great questions, we appreciate all of you who listened, who called in, who are watching us on Facebook live. By the way, Paul Hines is a professor of electrical engineering at the University of Vermont and his company is called Packetized Energy. If you like what you heard today, you might want to subscribe. We put a new episode out every two weeks and we love getting questions from all of you on any topic. If you're a curious kid and you have a question, have an adult, help you record it and then send a question to questions@butwhy kids.org. Today's live show is directed by Jake Rusnock. We had production assistance from Rick Barrett. It was produced by Melody Bodette, Sam Gale Rosen and me, Jane Lindholm and the Vermont Edition crew Ric Cengeri, Matthew Smith and Olivia White. Our theme music is by Luke Reynolds. Again, I'm Jane Lindholm. Thank you so much for being with us today. And stay curious!