KENDRA PUGH: Hi. Today, I'd like to talk to you about circuits. Last time, we finished up the LTIs, and signals, and systems, where we learned how to both model existing systems and predict their long-term behavior. But we haven't forayed into how to actually create systems in the physical world. We've created some amount of systems in software and made some brains for our robots. But if we want to make something in the physical world, then we probably have to come up with ways to model physical systems or use physical components. That starts our new model on circuits. Circuits are going to be our first foray into designing systems in the physical world, also designing systems using physical components.

It's worth mentioning now that the information that you learn about circuits is good for more things than even circuits. You can use basic circuit diagrams and properties of circuits to model all sorts of kinds of systems, especially ones in the human body-- circulatory system, neurological system, different kinds of fluid flow, that kind of thing. In the next few videos, we'll go over how to represent circuits, and also cover some of the basic methods by which people solve circuits. We'll also introduce an element called an op-amp, and use that element in order to enable us to do things like modularity and abstraction from our circuits.

First, let's talk about representation. In the general sense, when you come across a circuit diagram, you're going to see-- at the very broad level-- a bunch of elements and a bunch of connections between the elements. Those things will form loops and nodes.

If you don't actually specify the elements, then your circuit diagram actually looks a whole lot like a block diagram. And in fact, block diagrams and circuit diagrams are very closely related in part because block diagrams are used to model feedback systems, which frequently are implemented using circuits. In this course, we're going to be focusing on independent sources and resistors as the two major kinds of elements that we'll use in our circuits.

We'll also use things like potentiometers, which are resistors that you can adjust, and op-amps. And we'll look at op-amps specifically in a later video. But I have one drawn up here just so you recognize it when you see it written. Note that it looks a whole lot like the block diagram symbol for a gain. And that's intentional, and we'll cover that later.

But in the meantime, the other sources that we're going to be using are independent current, and voltage sources. We're going to use resistors to adjust the amount of voltage and current that we're actually dealing with and then sample either the current or the voltage at a particular point in our circuit to get the desired values that we're after. On a circuit diagram, when you're interested in the voltage drop across a particular element, you'll indicate it by putting a plus and minus sign. This also indicates the directionality of the voltage drop.

Likewise, when you're interested in the current flowing through a particular element, you'll usually see an indication of it by labeling the current i, and then maybe i with some sort of subscript, and an arrow indicating the direction of current flow through that element so that you avoid making sign errors with the person that might be reading or writing your diagram. A quick note here. This is the reason that electrical engineers use j to symbolize values in the complex plane. It's because i is used in particular for values of current.

Let's review Kirchhoff's voltage laws and Kirchhoff's current laws. You've probably covered this in 8.02, electricity and magnetism, or possibly in an AP physics class. But we're going to go over it really fast right now.

Kirchhoff's voltage law is that the voltage drop around a loop is equal to 0. Or if you take the voltage drop across a particular loop in your circuit, the sum of those voltage drop is going to be 0. Let's demonstrate on this diagram. Or, I'll demonstrate on this diagram.

Say the voltage drop across this element is equal to V, right? Doesn't matter what it is. We're going to stick with that. The voltage drop across these elements, if I were to move around this loop, is going to sum to 0. Note that if I'm tracing out my voltage drop across this loop, I'm actually moving through this voltage source in the direction opposite of its indicated potential. So when I move through this voltage source, I'm going to account for its value as negative V. As I work my way around the rest of the circuit, the voltage drop across these elements is going to sum to V.

This is true for all loops in my circuit. So any loop that includes V, the elements I encounter as a consequence of moving around that loop are going to have voltage drop equal and opposite to the value I get by moving through V in this direction. This loop counts, too, but it doesn't include V. All this loop tells me is that the voltage drop across this element is equivalent to the voltage drop across this element. Or, the voltage drop in this direction across that element is equal to the voltage drop in this direction across this element. That's Kirchhoff's voltage law.

Kirchhoff's current law is that the current flow into a particular node is equal to 0. Or, if you take all of the current flows in and out of a particular node and sum them, they should sum to 0. I've actually got the same set up here. I'm not going to use a current divider.

I'm interested in the current flowing over this element. It's actually the same as the current flowing over this element because resistance doesn't change current, resistors flowing through a resistor should not change the current. So this is still the same i. Here's my node. The current flowing in this direction and in this direction, if I took the linear combination of these two currents, they would be equal in value to the current flowing into this node.

When I'm looking at the current flowing through a particular node, I pick a direction. It's usually arbitrary. I pick a direction. It's arbitrary which direction I pick. Typically, you pick currents flowing into the node as being positive. I sum up all the currents, and I set that equal to 0. So in this case--. Or-- pretty simple.

Let's practice on this particular circuit. One thing to note is that when you're solving circuits in the general sense, both when you want TA help and when you're solving for a mid-term and want partial credit, you want to label all of your nodes, all of your elements, and all of the currents that you're interested in solving. See, I've got my voltage drop across this resistor, this resistor, and this resistor labeled, as well as these currents, which I'll also be solving for.

The first thing that I would do when approaching this problem is attempt to reduce this circuit to something that is a little bit simpler. The first thing that I'm going to do is try to figure out how to change these two resistors in parallel into a single resistor and still have an equivalent circuit. That'll allow me to solve for I1. There will be 0 nodes in my system. I'll just have one single loop. And the current through the system will just be V/R.

So if I'm just looking at these two resistors, I have resistors in parallel. In the general sense, the way to solve for resistors in parallel is to take the inverse of the sum of their inverses. When you only have two resistors, you can typically cheat by saying that this is equal to their product over their sum.

I'm going to redraw my current understanding of the circuit. The other stuff that I've saved myself is that because these resistors are in parallel, they're a current divider. They take the current in and divide it two ways determined by the ratio between these two values. The thing I'm actually interested in expressing is that V2 and V3 are the same value. When you have a current divider, the voltage drop across all elements in the current divider are the same. So the value of V here is going to be both V2 and V3. 2R plus 6/5 R. I'm going to go with 16/5 R for now. I've solved for I.

At this point, I have a voltage divider, which means that the current flowing through this part of the system is going to be the same. But the voltage drop across this element versus this element is going to be proportional to the ratio between these two values. V1 is going to be the amount of the total resistance in this simple circuit that this resistor contributes over the entire resistance in the system. Or, 10/5 R over 16/5 R, which is 10/16 R, or 5/8 R. Or, it's going to be 5/8 V.

Same thing happens with V2. Note that these two values should sum to V in order to maintain Kirchoff's voltage law. We've also found V3. So the two things that we have to find are I2 and I3.

Here, I've just done Kirchoff's current law for this node. Because I'm working with a current divider, I can break up the total current flowing into that node into the number of parts equal to the sum of these values and then distribute them. And then, that's [? inappropriate ?] given that less resistance means more current. What do I mean by that?

Well, I mean that here my current is equal to 5/16 V over R. I2 is going to be equal to this value over the sum of these two values times I1. Likewise--. And just to simplify--.

That concludes my tutorial on circuits. Next time, we'll talk about other ways we can solve this circuit, and then we'll end up talking about op-amps.