<u>Capacitive Reactance</u>

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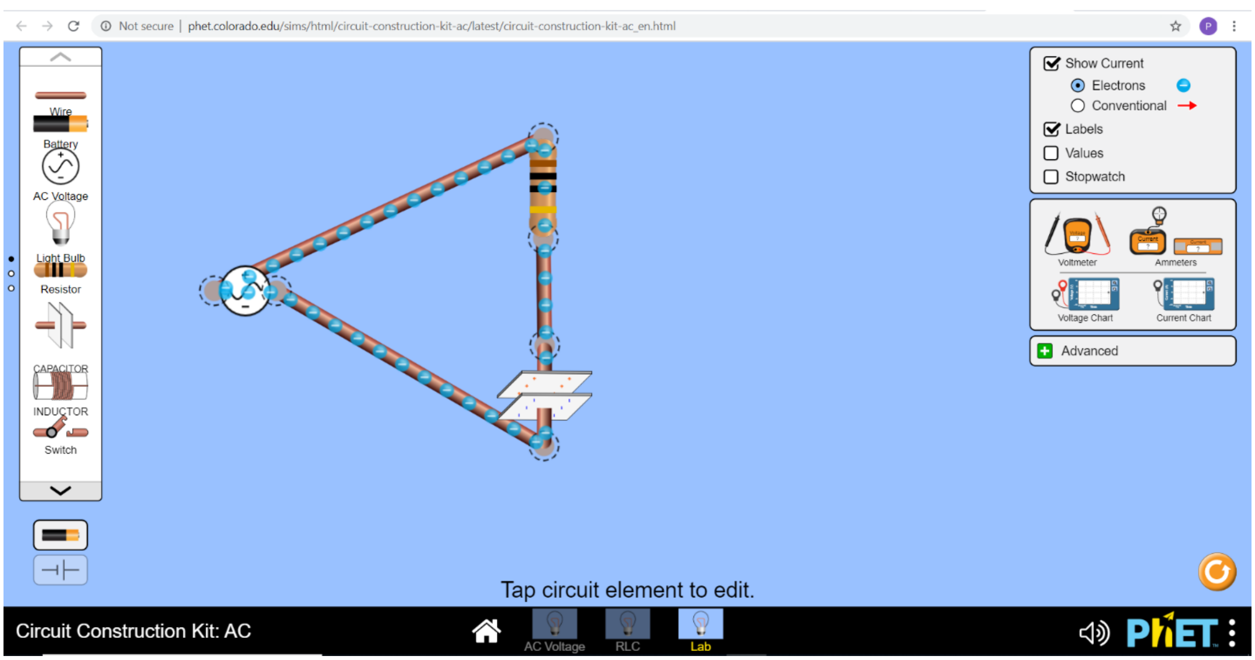
Go back to

http://phet.colorado.edu/sims/html/circuit-construction-kit-ac/latest/circuit-construction-kit-ac_en.html

and click twice on the Lab icon to return to the empty lab screen.

Drag from the white component box on the left an AC voltage source, a resistor and a capacitor, and wire them in series. They might look like this:



You can see the electrons sloshing back and forth. You can also see each capacitor plate charging positive and then negative and then positive again.

Drag out the voltage chart and measure the amplitude of the voltage across the resistor. Now measure the amplitude of the voltage across the capacitor. Click on the AC source to check the amplitude of the voltage being supplied by the source.

If we had a DC circuit like the ones you worked with in January, the sum of the voltages across the two circuit components in series would add up to the voltage supplied by the DC source (power supply or battery). Do the voltages across the resistor and capacitor in this circuit add up to the voltage supplied by the AC source?

The answer, of course, is no. So what is going on here?

Let's back up. I mentioned in the last lab that it is convenient to define a resistance-like quantity for capacitors and inductors in AC circuits. Ohm's Law – which works for resistors – says that V=IR. Now drag the current chart out into the blue area, and connect the current sensor to each of the three wires (one between the AC source and the resistor, one between the resistor and the capacitor, and one between the capacitor and the AC source) and see if the amplitude of the current is the same in all three wires. Does Ohm's Law work for the resistor in this circuit? Is the amplitude of the voltage equal to the product of the resistance and the amplitude of the current?

If we wanted to treat the capacitor like a resistor, we would have to come up with a quantity we could call X_C, the capacitive reactance, that would obey the equation

$V_C = IX_C$

What is the amplitude of the voltage across the capacitor? What is the amplitude of the current in the circuit? What would you then deduce is the capacitive reactance of this capacitor?

Now double the frequency. To do that, click on the AC source – that will make a slider for frequency appear. The default frequency for the sim is 0.5 Hz. If that is what you made your first wave of measurements at, then double the frequency to 1.0 Hz. Did the amplitude of the voltage across the capacitor increase or decrease? What is the amplitude of the current now? Did the capacitive reactance change? Did it get bigger with the increase in the frequency or smaller?

Pull out your "AC Circuit Cheat Sheet" and look at the equation for the capacitive reactance. Does it make sense that the reactance is smaller for a given capacitor at a higher frequency? (Recall that the angular frequency ω is equal to 2π times the frequency)

Now compare the phases of the voltage across the capacitor and the current. Do the voltage and the current reach their peaks at the same time? If not, by how much of a period do the times at which the voltage and current reach their peaks differ?

The AC Circuit Cheat Sheet says that the voltage across the resistor and the current reach their peaks a quarter of a period apart. (For a capacitor, the current leads the voltage by a phase angle of $\pi/2$. Since a full period equals a phase angle of 2π, that means the current leads the voltage by one-quarter of a period.)

So back to the issue of why the amplitudes of the voltages across the resistor and capacitor do not add up to the amplitude of voltage supplied by the AC source. The physics you learned with DC circuits is still valid; that is, *at any given moment the sum of the voltage drops across the resistor and capacitor must equal the voltage supplied by the AC source.* But from seeing that the current and voltage across the capacitor are not in phase (and that the voltage across the resistor and the current *are* in phase) you can see that the amplitudes don't have to add up –

the laws of physics are satisfied even though the amplitudes of the resistor and capacitor voltages don't add up to the amplitude of the voltage supplied by the AC source.