Learning Electrical Engineering Basics through an Infrared Controlled Circuit

Ages 8-10, 11-13

Approximately 2 hours, 15 minutes

Learning Objectives:

Students will be able to understand the concepts of voltage, current, and resistance, and will become familiar with common circuit components. Students will learn about energy carried in light and energy transfer. Students will gain hands-on experience building a circuit, and will be able to customize their designs.

Materials:

- For the voltage, current, and resistance demo:
  - ¾" x 2' PVC Pipe
  - 3" x 2' PVC Pipe
  - 3" PVC Pipe Caps
  - A large bucket for water
  - Water*
- For the infrared controlled circuit
  - 1.5V DC Motor (1 per student)
  - IR Remote (students can share remotes)
  - CR2025 Coin Cell Batteries for IR remotes (1 battery per remote)
  - AA Batteries (2 per student)
  - AA Battery holder (1 per student)
  - Wire kits (1 per 5 students)
  - Breadboards (1 per student)
  - IR Receiver TSOP 38283 (1 per student)
  - 7555 Timer Chip (1 per student)
  - BC547 Transistor (1 per student)
  - BC337 Transistor (1 per student)
  - .1 uF Capacitor (1 per student)
  - 1 uF Capacitor (1 per student)
  - 10 uF Capacitor (1 per student)
  - 18K Resistor (1 per student)
  - Ribbon, streamers, and tape (to share)*

* Denotes single use materials. All other materials are re-usable.

Attachments:

- Budget sheet, with itemized parts list for purchasing components
- Picture slideshow

Preparation:

- For **ages 8-10**, the battery and motor should be connected into the right place in the circuit. All wires should already be placed in the circuit. Students will place the components in themselves.
- For **ages 11-13**, the 555 timer should be placed in the circuit, but nothing else.
- Make sure that the CR2025 coin cell batteries have been put into the infrared remotes (batteries are not included in the remotes).

Lesson:

Voltage, Current, and Resistance (30 minutes)

- Ask students to raise their hand if they have seen a circuit before, or know what a circuit is.
    - Ask some students with raised hands to explain. If no one has seen a circuit, give some examples of where students might see circuits (inside their TV remotes, in their refrigerator, inside their computers, etc.)
- Ask students to raise their hand if they have heard of voltage or current. Then ask if anyone knows what voltage or current is.
    - Ask some students with raised hands to explain their thoughts on voltage or current.
- Explain that voltage and current are just measurements to measure how electricity is flowing in a circuit. Say that electricity flows in a circuit just like water flows in a pipe.
- Explain that we are going to look at water flowing through a pipe to understand how electricity flows in a circuit. Draw this chart on the board, but leave the entries below "In a Pipe" and "In a Circuit" blank at first.
- Ask students to suggest some factors that affect the way that water flows through a pipe. To get the students started, add "water" below the pipe column of the chart, and explain that we might want to think about how much water is in the pipe.
    - If students suggest factors that are not in the chart, describe with different words the factors we are looking for (pressure, flow, and pipe width) and see if the students can come up with these names.

In a Pipe	*In a Circuit*
Water	Charge
Flow	Current
Pressure	Voltage
Pipe width	Resistance

- At this point, the first column of the chart should be filled, but the circuit column should be empty.
- Ask the class how they think the amount of water in the pipe can be related to a circuit.
    - If the class is quiet, ask them what they think is flowing in a circuit, instead of water. Is it electricity? It's charge (electrons). Fill in the chart with this.

- Explain to students that the water flowing in a pipe is like charge flowing in a circuit. Ask students if they know what the term for the flow of charge in a circuit is called.
    - It's called current, so now you can fill that box in in the chart.
- Ask for three student volunteers to come to the front of the classroom to help with the pipe demonstration.
    - One student will hold the 3" pipe, one will hold the stopper at the end of the pipe, and one will pour water into the pipe.
- Ask one of the students at the front of the room to fill up the pipe with just a little water. Ask the student holding the stopper at the end of the 3" pipe if they felt a change in pressure, or difficulty holding the stopper in place, when the water was added.
    - They should feel a change in pressure, because of the weight of the water, but if they don't, add more water.
- Ask the student to release the stopper, releasing all the water (into the bucket). The volunteers can return to their seats.
- Ask the class what they think the pressure of the water is equivalent to in a circuit. As we add more water, the pressure goes up. In a circuit, when we add more charge, what changes in the circuit?
    - Explain that when the amount of charge changes in a circuit, the voltage changes. Voltage is the potential difference between two points. If one side of a circuit has a lot more charge then the other side, then there is a big voltage between the two sides. Just like in the pipe, there is a lot of water at the top of the pipe, but no water at the bottom of the pipe, which creates a big pressure for the student holding the cap.
- Now there is just 1 box left to fill out for the pipe width equivalent in a circuit. Ask students if they can think of a way to make the two pipes of different widths have the same water flow.
    - If no one gets it, suggest that we fill the thinner pipe with more water. This will create more pressure in the pipe (since there is more water) which will force water out of the pipe faster, increasing the flow in the smaller pipe, and making it the same as the bigger pipe.
- Ask five new volunteers to come up. Ask them to pour more water into the ¾" pipe than into the 3" pipe. Ask them to release the stoppers.
    - The small pipe should ideally empty all its water at the same time as the big pipe.
    - Notice that the pipes are emptied at much closer to the same time as before, which means their flow rates are closer.
- Ask the students to take a seat.
- Explain that changing the pipe width changes how much water can flow through the pipe at a given pressure. Ask the class: in a circuit, what can we change that limits the amount of charge that can flow through the wires?
    - Explain that we can change something called the "resistance". This is the same as changing the pipe widths to limit water flow. Resistance limits current flow in a circuit.

- Now the class will learn some more specific circuit components. Using the concepts in the board, explain each of these components as follows:
    - Capacitor – show the picture of the capacitors on the projector. A capacitor is basically a bucket or receptacle of charge. Students can think of a capacitor like a bucket of water. When charge (water) flows into the capacitor (bucket) it retains that charge. The capacitor will discharge (equivalent to a bucket releasing its water) when a set voltage (or level of charge) is no longer mandated. For example, if a plumbing system no longer requires that the bucket have water in it, the water in the bucket will begin to leak out, until it is empty.
    - Transistor – show the picture of a transistor on the projector. A transistor is essentially a switch. When a high enough voltage is applied to the base terminal of the transistor, the transistor turns "on", and essentially becomes a wire connecting the top and bottom of the transistor. When the transistor does not have a high enough voltage at the base, it is "off", and the top and bottom of the transistor are disconnected. Students can think of a transistor like a faucet, that either lets water flow or doesn't.
    - 555 Timer – show the picture of the 555 timer. The 555 timer is a type of IC chip (integrated circuit). Tell the students that there is actually a tiny little circuit in the black plastic that they will use for their project.

Energy of Light (20 minutes)

- Explain to class that later during the lesson, we will be using infrared light to control a circuit, so we need to understand how light will interact with our circuit.
- Ask students to help make a list of some properties of light. As the students give suggestions, write them down on the board.
    - If the class is quiet, give a few example suggestions, such as the color of the light. One property to suggest at the end of this brainstorming session is wavelength.
- Ask students if anyone knows what the "wavelength of light" means.
    - Explain that even though beams of light look straight, light is actually in the shape of waves. The waves are so tiny that we can't see them with the human eye. Light can be measured based on its wavelength, or how long these waves are.
- Ask the class if anyone has heard of the electromagnetic spectrum before.
- Display the electromagnetic spectrum to the class with a projector.
    - Explain that light at one end of the spectrum has a really long wavelength, and light at the other end has a really short wavelength. The projected image will have some examples of the wavelengths so students can relate (ie, radio waves have wavelengths that are roughly the height of sky scrapers).
- Ask students if they think we can see all types of light. For example, radio waves and microwaves are emitted by radios and microwaves respectively. Can we see those types of light?
    - The answer is no. We can only see a small part of the spectrum!

- Explain that the energy carries in light depends on the wavelength. Explain that the energy in light can be used to power other things! Ask if anyone can think of an example of light being used to power something.
    - One example is solar panels.
- Ask two students to come to the front of the classroom. Take the tray of water and shift it slowly, creating long waves in the tray. Then, shake the tray faster, and the waves in the tray will be shorter. Ask the students at the front to tell the class what they see in the tray. Then ask them to take a seat.
    - Explain that when you shake the tray with less energy, the wavelength of the waves is longer. When you shake with more energy, the wavelength is shorter. This is also true for light waves (shorter wavelength means higher energy carried in the wave).
- Explain that in our project, we want to use the energy in infrared light to power a motor.
- Point out that there are different types of energy, and energy carried in light is only one type of energy. In order to use the energy in light to power other systems, we will need to convert the energy in light into mechanical energy.
- Ask the students to help figure out how to convert the light energy into mechanical energy for the motor. Begin by drawing this chart on the board, but leave the 2nd row blank:

Infrared Remote Controller	**Circuit**	**Motor**
Light energy	Electrical energy (potential energy)	Mechanical energy (kinetic energy)

- Ask the students to help fill in the 2nd row of the chart. Ask what types of energy they think exist in the remote controller, the circuit, and the motor. Lead the discussion towards the correct answers and fill out the chart.

Break (10 minutes)

- While students are on a break, use this time to set up for the circuit project. Place a set of necessary components at each student's desk.

Building the Circuit (40 minutes)

- Display the schematic of the circuit on the projector. Explain once more what the circuit will do (transfer energy from the infrared light remote controller into electric potential energy that will spin a motor).
    - The connections on this diagram will be the same color as the colored wires in the physical circuit.
- On the same screen, also display a picture of a finished circuit. This should help students wire their circuits correctly.
    - **Ages 8-10:** The battery and motor should be connected into the right place in the circuit. All wires should already be placed in the circuit. Students will place the components in themselves.

    - **Ages 11-13**: The 555 timer should be placed in the circuit, but nothing else.
    - Notice that the wires are different colors. Ask students to use the same colored wires as in the picture to make debugging simpler.
- Explain that after building the circuit, students will get to customize their design with ribbons and streamers.
- Explain that when students are done building, they should be able to press a button on the remote and see the motor spin.
    - Encourage students to ask a volunteer for help throughout the build process if they have questions or if their circuit isn't working.
    - Encourage students to check each other's circuits if they are having problems.
- Let students start building, and volunteers should circle around the classroom at this point, answering questions and helping students build their circuit.

Crafting and Personalization (20 minutes)

- Let students tape ribbon and streamers to their motor, so that the ribbon and streamers will fly around when the motor spins.

Presentations (15 minutes)

- Ask students to form groups of 5 amongst themselves. In their groups, ask them to present their craft and designs to each other, and explain how they came up with their craft design.
- During this time, students should be socializing and playing together with their designs.

Common Questions and Issues

Question - What is a capacitor, transistor, or 555 timer chip?

- A capacitor is basically a bucket or receptacle of charge. Students can think of a capacitor like a bucket of water. When charge (water) flows into the capacitor (bucket) it retains that charge. The capacitor will discharge (equivalent to a bucket releasing its water) when a set voltage (or level of charge) is no longer mandated. For example, if a plumbing system no longer requires that the bucket have water in it, the water in the bucket will begin to leak out, until it is empty.
- A transistor is essentially a switch. When a high enough voltage is applied to the base terminal of the transistor, the transistor turns "on", and essentially becomes a wire connecting the top and bottom of the transistor. When the transistor does not have a high enough voltage at the base, it is "off", and the top and bottom of the transistor are disconnected.
- A 555 timer chip is a type of IC chip, which stands for integrated circuit chip. An IC chip usually looks like a little black box with metal legs sticking out of the sides. An IC chip has a tiny circuit inside of it, and the metal leads are simply the inputs and outputs of the internal circuit. In this case, we are using a 555 timer. This IC has an internal circuit that creates a "clock" signal, which is an AC signal (like a sine wave) at a particular frequency.

Issue - Large class size

- Ask students to check each others circuits (in groups of two or three) to help eliminate the teacher's time spent debugging.
- If there are not enough supplies for all students to build their own circuit, ask students to work in pairs to build a circuit.
- Many students can share a single IR remote if remotes cannot be purchased for the entire class. Furthermore, a common TV remote from home can also serve as the IR remote for this project.

Issue - Circuit Debugging Issues

- If a circuit doesn't work, check the wiring, particularly the connections to the 555 timer chip, since these connection ports are close together and easy to confuse (especially for young students).
- Check that the batteries are fresh.
- Check that no two nodes are shorted together. If you hold a breadboard vertically (short side facing you) the horizontal rows of holes are internally connected. So, no two connections should be placed on the same horizontal line, or they will be shorted together.