Circuits Part 3: Electromagnets & Capacitors

**Electromagnets**
We've actually already worked with an electromagnet---the speaker in your toy has one. You've probably noticed that the speaker has a magnet because metal pieces keep sticking to it, and you’ve seen the electromagnet---it’s the small coil of wire visible through the clear plastic cover of the speaker. Let’s look at how an electromagnet works and then play with them for awhile---they allow us to do amazing things.

Begin by looking at [this animation](#). So far we have learned a little bit about electricity but not much about magnetism. It was once thought that these were separate forces but we now know that they are two sides of the same coin. Electromagnetism manifests as both electric fields and magnetic fields. Both fields are simply different aspects of electromagnetism, and hence are intrinsically related. A changing electric field generates a magnetic field, and, conversely, a changing magnetic field generates an electric field. This effect is called [electromagnetic induction](#), and is the basis of operation for [electrical generators](#), [electric motors](#), and [transformers](#).

**Relays**
In the last exercise we worked with switches and a relay is a switch; it’s an electrically operated switch. It is made up of an electromagnet and a set of contacts. Relays are found hidden in all sorts of devices. In fact, some of the first computers used relays to control the flow of electricity through their circuits. As explained in [this animation](#), when electricity runs through a relay’s electromagnet, the resulting magnetic force pulls a springy strip of metal to close a switch. So long as the relay is “energized,” its switch remains closed. When the flow of current through the electromagnet stops, the springy strip of metal snaps back to its original position and opens the switch.

Relay switches come in many configurations: SPST, DPST, SPDT, and so on. If you are not familiar with these terms, review the [animation on switches](#) posted last week. We have a SPDT relay with the pin layout show below.
Pins 2 and 9 are the connections to the electromagnet coil. Pins 5 and 6 are the connections to the pole. And the pole (pins 5 & 6) is connected to pin 1 when the relay coil is not energized, and connected to pin 10 when the relay coil is energized.

Your first job is to place the relay on the breadboard as shown. Notice that the relay must span the trough in the middle of the board and this is hard to do. The pins of the relay must be bent and pressed very firmly into the holes of the board.

Once the relay is positioned, connect the coil to power and ground. Manually connect and disconnect power to the coil. Make sure that you can hear the coil energize each time power is applied. If you can’t hear the coil energize, ask your instructor for help.

Next replace your manual switch (i.e., connecting and disconnecting the wire) with a pushbutton switch as shown. Check your switch and make sure it works----you should still be able to hear the coil energize.
Now let’s see the relay do its job. Connect an LED to each side of the switch. Ground the other end of each LED. There should be one LED connected to pin 1 and one LED connected to pin 10. Feed power into the pole via pin 5 or pin 6. Be sure to use a 330 Ohm resistor to connect to power as shown below.

If you have successfully created this circuit, you should see one LED glow when the coil is not energized and the other LED glow when the coil is energized. This is characteristic of a single pole double throw switch.

**Speakers**

Let’s reconfigure the relay to control the output to a speaker. We’ll use the speaker from your toy so begin by removing that speaker. If the speaker leads are damaged or if you prefer to replace them with single strand wire, solder new connections to your speaker. Create the circuit below. Notice that the resistor connecting pin 6 to power has been replaced with a wire.

Energize the relay and make note of your observations. Did you hear anything more than the coil? Touch the speaker when you energize the coil—do you feel anything? View this [demonstration of a speaker](#) and be prepared to explain what you heard (or didn’t hear) when you energized the relay. Do you recognize the electromagnet in the speaker?

**DC motors**

The last application of an electromagnet that we’ll play with today is an electric motor. View this [animation](#) to understand how an electromagnet is used to create an electric motor. Now remove the speaker from the circuit above. Connect the positive lead of the DC motor to pin 6 of the relay. Connect the negative lead to ground. Hold the motor before you energize the relay so it doesn’t run away from you 😊
Now for something completely different: an oscillator

Let’s have some fun by making our switch (the relay) oscillate. We can do this by running power first to pin 10 (the pin that’s engaged when the coil is not energized), and then from the pole (pin 6) to the coil. Leave the opposite end of the coil connected to ground. In this configuration (shown below), power initially flows to the coil through the connection to pin 10 until the coil energizes and switches the connection away from pin 10 over to pin 1. When pin 1 is connected to the pole, the coil de-energizes, and the switch moves away from pin 1 back to pin 10. And the cycle repeats. Of course, this process is rather hard on the poor relay. You’ll hear it vibrate, and as soon as you do, release the pushbutton switch controlling the relay to break the cycle.

To make this more interesting, connect a device to pin 1 so that it can oscillate as the relay does. As depicted below, you can connect an LED for this purpose. Can you see it oscillate? If not, why not?
Capacitors
If you guessed that the power to the LED was oscillating so rapidly that the fluctuations were not detectable, you were right. To slow the oscillations we’re going to add a capacitor to the circuit. A capacitor is like a tiny rechargeable battery. It is so small that it charges in a fraction of a second, before the relay has time to switch. Then when the relay switches, the capacitor acts like a battery, providing power to the relay. It keeps the coil energized for a short period after the relay has switched. After the capacitor exhausts its power reserve, the coil de-energizes and the process repeats. Watch this animated description of a capacitor for a more complete description of how it works.

You have access to several capacitors each with a different charge capacity which is measured in farads. Add the different capacitors to the circuit one at a time starting with the smallest capacitor (the smallest farad rating). The circuit you want to create is shown below. Note that the capacitor is spanning the coil in the relay. **WARNING**: You have electrolytic capacitors and they are polarized. They must be orientated properly in the circuit or they can **EXPLODE**. The long leg must be orientated to the + side (high power side) of the circuit and the short leg to ground. If you are at all uncertain of how to connect the capacitor, ask your instructor for help.

Try each capacitor in turn and note its effect on the oscillations of the relay as apparent in the LED. What can you conclude?

Now replace the LED with a speaker and repeat the experiment. Try each capacitor in turn and note the sound produced by speaker. How does the sound change with each different capacitor? Are your observations consistent with those made using the LED?
Time to quit and go home.