Building an RC Circuit: Neon Bulb Relaxation Oscillator

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PHYS 690

**Abstract**

Building a simple RC circuit is an effective way to teach how capacitors work. Known as a relaxation oscillator, this particular circuit causes a neon lamp to blink which allows students to observe this phenomenon and develop insight. This electric circuit is analogous to a Japanese garden fountain mechanical relaxation oscillator, the shishi-odoshi or “deer scarer”.

**Bio**

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**Background**

Although they are not featured in most basic Physics curricula, RC circuits can serve a purpose when teaching current electricity (Steinberg, 2011). A student misconception regarding capacitors is that the electrons "jump across" the capacitor after it has charged. This idea stems from not fully understanding how a parallel circuit works. Building your own RC neon bulb circuit can provide a thought provoking conversation, since the neon bulb is able to indicate direction of electron flow as it lights and should already be familiar to students from electrostatic investigation (Wilser & MacIsaac).

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| NYS Regents Physics Standards | 4.1n A circuit is a closed path in which a current can exist. 4.1o Circuit components may be connected in series or in parallel. Schematic diagrams are used to represent circuits and circuit elements.(Physical Setting, 2015) |
| Modeling Physics Instructional Goals | Electricity, U3: Circuits 4. For simple series and parallel circuit arrangements, conservation of energy and charge can be demonstrated.* The energy dissipated by resistive elements in a circuit equals the energy provided by the external source.
* The total quantity of charge moving in a circuit remains constant. The quantity of charge in a given branch is inversely proportional to the resistance in that branch.

6. Representational tools include:* maps of surface charge distribution
* schematic diagrams to represent circuits.

(AMTA, 2014) |
| CASTLE Curriculum Instructional Goals | U2: Charge Flow and Sources of Charge Model* Represent simple circuits with schematic diagrams.
* Identify the structure/parts of a capacitor.
* Indicate the direction of charge flow throughout a circuit during capacitor charging and discharging.

(Steinberg, 2011) |

**Constructing an RC Circuit**

An RC circuit is a circuit which contains a resistor and a capacitor, hence the name RC. Here it is used as a tool to teach about capacitors as well as the behavior of current electricity. Upon observations of a RC circuit, students see a neon bulb that blinks. Additionally, because it is a neon bulb, the direction from which the current is flowing can be determined. Neon bulbs consist of two electrodes. Whatever side the current is flowing through the bulb from, the closer electrode will glow. Having students question why the light is blinking is what starts to provide insight into how capacitors work.

To construct the RC Circuit, you will need the materials listed in Figure 4 (MacIsaac and Wilser, Caplan 2008). For an external source, the easiest method is to use ten 9 Volt batteries connected together in series (Caplan, 2008). The circuit can be mounted on a piece of wood or particle board and should be the capacitor and the neon bulb wired in parallel with a resistor in series, as shown in Figure 1.

 To address the Physics content of why the light is blinking an oscilloscope can be used to measure the voltage across the capacitor. As seen in Figure 2, there is a clear interval at which the capacitor has enough voltage to cause the light to “blink” at which point the capacitor loses some voltage (Wilser & MacIsaac). As the capacitor charges back up and the bulb remains unlit until it reaches the same voltage as the previous “blink”.



 Figure 1: Relaxation Oscillator diagram

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Math

Charging Vc = V0(1-e-t/RC)

Discharging Vc = V0(e-t/RC)

Vc =Voltage across Capacitor

V0 = Supply Voltage

t = time since supply voltage applied

RC = time constant of RC circuit

 (Resistance x Capacitance)

Figure 2: Time dependence of voltage

 across capacitor (Wilser & MacIsaac)

R=1Mr \*Time for RC circuit should be ≈ 1 second

C=1μF

**The Shishi-Odoshi Analogy: A Mechanical Relaxation Oscillator**

The term “relaxation oscillator” really means that the system is binary. The focal point of the oscillation is either on or it is off. An example of a mechanical relaxation oscillator is the Japanese garden fountain known as the shishi-odoshi. As seen in Figure 3, the shishi-odoshi is a tube which fills up with water and when the tube gets too full, it tips and the water comes pouring out. This comparison between the shishi-odoshi and the capacitor is a much more real world example that students can actually observe.



Figure 3.

[**http://www.japanesestyle.com/sites/default/files/deer\_chaser.jpg**](http://www.japanesestyle.com/sites/default/files/deer_chaser.jpg)

**(Possibly replaced by a Buffalo State picture)**

Shishi-Odoshi analogy

Where the analogy works

|  |  |  |
| --- | --- | --- |
| RC Circuit | Shishi-odoshi | Short explanation |
| Electrons  | Water | Water flows through the apparatus similarly to the charge in a circuit |
| Capacitor  | Fill tube | The fill tube holds a certain amount of water just as the capacitor holds a certain amount of charge |
| Discharging Capacitor  | Emptying feedpipe | As both become full, they discharge and release the buildup of what has collect. |
| Charge | Mass  | The circuit is driven by charge, this can be compared to how the fountain is driven by mass. |
| Electric Field | Gravity  |  The shishi-odoshi operates with earth’s gravitational field which provides gravitational potential energy to just as the circuit has an electric field and electric potential. |
| Limiting Resistor | Feedpipe | Both limit the size of the discharge that the system undergoes. |

Where the analogy does not work

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| --- | --- | --- |
| RC Circuit | Shishi-odoshi | Short explanation |
| Can’t remove charge | Manually remove water  | Unlike a hose or a pipe, one cannot pick up a section of wire and shake all of the charge out of it. |
| Magnetic Field | No “water field” | The water flowing in the shishi-odoshi does not create a field like the magnetic field created by the current in the circuit. |
| Positive and Negative Charge | No “antiwater” | The water in the shishi-odoshi is simply water, there is no comparison to account for positive and negative charge in a circuit. |
| Current | Flow Rate | Current changes in the RC circuit but the flow rate stays constant in the shishi-odoshi. |

**Materials and where to get them:**

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| --- | --- | --- | --- |
| Component | Price each | mouser.com | digikey.com |
| Ne-2 bulb (or equiv) | $0.34 | 606-A9A |  |
| 1.0 MicroFarad 100V Capacitor | $0.32 | 581-BN154E0105K | 399-5455-1-ND |
| 1 MegaOhm 1/4Watt carbon film resistor | $0.04 | 291-1M-RC | P1.0MBACT-ND |
| 9V Batteries (10) |  | Old batteries from smoke detectors will work, Ask students to bring them from home. |  |
| Particle Board |  |  |  |

Figure 4. (Wilser and MacIsaac, Caplan 2008)

**Summary**

 Resistor Capacitor circuits can be used to address some common learning objectives that span across several different physics curricula. In discovering how a capacitor works students can begin to understand how circuits work in general. This can be aided by the usage of analogies to the RC circuit from the shishi-odoshi, which uses water analogous to charge well as ideas from mechanics that students should be much more familiar with.

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