Topic: RC & RL Circuits
Related Reading:
        Course Notes (Liao et al.):   Sections 7.5 – 7.6, 11.1 – 11.4
Experiments: (6) RC and RL Circuits

Topic Introduction

Today we will investigate the behavior of DC circuits containing resistors and either capacitors or inductors (RC & RL circuits). We discussed their behavior in the class before the most recent exam. Now, in experiment #6, you will have a chance to measure their behavior yourself.

RC & RL Circuits

A simple RC circuit is shown at right. When the switch is closed, current will flow in the circuit, but as time goes on this current will decrease. We can write down the differential equation for current flow by writing down Kirchhoff's loop rules, recalling that $|\Delta V| = Q/C$ for a capacitor and that the charge Q on the capacitor is related to current flowing in the circuit by $I = \pm dQ/dt$, where the sign depends on whether the current is flowing into the positively charged plate (+) or the negatively charged plate (-). The solution to this differential equation shows that the current decreases exponentially from its initial value while the potential on the capacitor grows exponentially to its final value. The rate at which this change happens is dictated by the "time constant" τ, which for this circuit is given by $\tau = RC$.
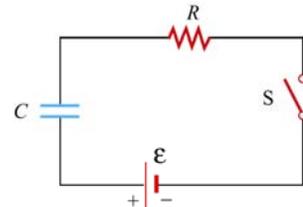
If we replace the capacitor with an inductor we find a similar but opposite result. Now the current starts at zero and "decays" upward to a constant value, now with a time constant $\tau = L/R$ (a big inductance slows down the circuit as it is more effective at opposing changes, but now a big resistance reduces the size of the current and hence changes in the current that the inductor will see, and thus decreases the time constant – speeds things up).
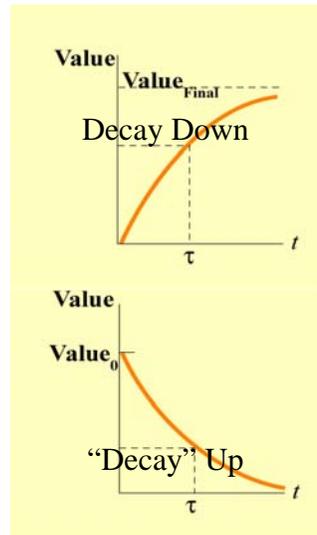
Interestingly, in RC & RL circuits any value that you could ask about (current, potential drop across the resistor, across the capacitor, …) "decays" exponentially (either down or up). You should be able to determine which of the two plots at right a value will follow just by thinking about it.

Experiment 6: RC and RL Circuits
Preparation: Read pre-lab and answer pre-lab questions

This extended lab will introduce you to the techniques of measuring current and voltage in a circuit and then allow you to observe the exponential behavior of RC and RL circuits as they are "charged" and "discharged" using a battery which periodically turns on and off. You will measure the time constant of several circuits and investigate how it changes as resistance, inductance or capacitance are modified.

Important Equations

Self Inductance, L:

$$L = \frac{\Phi_B}{I}$$

EMF Induced by Inductor:

$$\mathcal{E} = -L\frac{dI}{dt}$$

Exponential Decay: $Value = Value_{initial}\, e^{-t/\tau}$

Exponential "Decay" Upwards: $Value = Value_{final}\left(1 - e^{-t/\tau}\right)$

Simple RC/RL Time Constant: $\tau = RC$; $\tau = L/R$