Warm-Up for May 2nd, 2022

Dr. Jordan Hanson - Whittier College Dept. of Physics and Astronomy

May 1, 2022

1 Memory Bank

1. Current density, and Ohm's Law: $\mathbf{J} = \rho\mathbf{v}$, $\mathbf{J} = \sigma\mathbf{E}$, $\Delta V = IR$.
2. Note about current and capacitors: $dQ/dt = I$, $Q = C\Delta V$.
3. *Flux rule for motional emf*: $\mathcal{E} = -d\Phi_B/dt$
4. Definition of self-inductance, or just **inductance**: $\Phi_B = LI$.

2 Current and Ohm's Law

1. (a) Assume that moving charges in current have two velocities: the *drift velocity* v_{ave} in the direction of current flow, and a *thermal velocity* v_{th} in random directions. Let $v_{\text{th}} = \lambda/t$. Show that the average velocity of an object that is accelerating for a short time t is $v_{\text{ave}} = \frac{1}{2}at$. (b) Substitute t with λ/v_{th}, and inserve v_{ave} into the definition of current density from the memory bank. (c) Show that $\mathbf{J}$ is proportional to $\mathbf{E}$, even though current has a constant drift velocity v_{ave}.

2. A capacitor C has been charged up to potential V_0; at time $t = 0$, it is connected to a resistor R, and begins to discharge (Fig. 1, left). (a) Determine the charge on the capacitor as a function of time, $Q(t)$. What is the current through the resistor, $I(t)$? (b) Show that the integral of $P(t) = I^2(t)R$, the energy delivered to the resistor, is $W = \frac{1}{2}CV_0^2$. (c) Now imagine charging up the capacitor (Fig. 1, middle). Determine $Q(t)$ and $I(t)$. (d) Find the total energy output of the battery ($\int V_0 I dt$). What fraction of the battery output shows up in the capacitor?

3. For the RL circuit of Fig. 1 (right), what is $I(t)$?

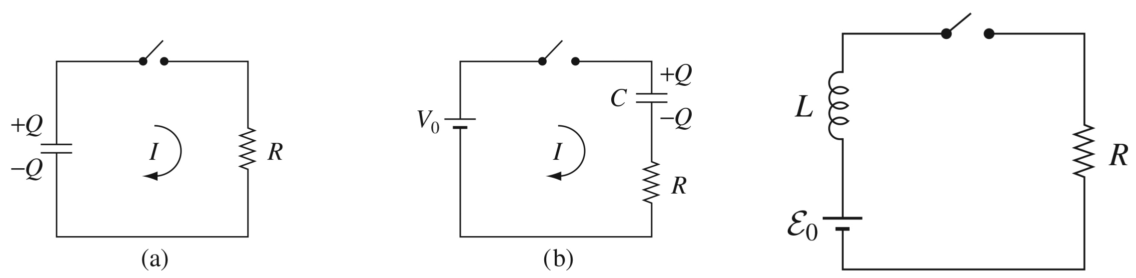

Figure 1: Two circuits: (left) RC circuits, and (right) the RL circuit.