1. KCL: \[ I_1 = I_2 + I_3 \]
   KVL: \[ V - I_1 R_1 - I_2 R_2 = 0 \]
   \[ V - I_1 R_1 - I_3 R_3 = 0 \]
   Solve: \[ I_1 = V \frac{R_2 + R_3}{R_1 R_2 + R_1 R_3 + R_2 R_3} \]
   \[ I_2 = V \frac{R_3}{R^*} \]
   \[ I_3 = V \frac{R_2}{R^*} \]

2. At \( t = 0 \), capacitor acts like a short circuit.
   At \( t = \infty \), acts like an open circuit.

\[ t = 0: \]
\[ \begin{array}{c|c|c|c|c|c|c|c|c|c}
   & & & & & & & & & \\
   & & & & & & & & & \\
   & & & & & & & & & \\
   & & & & & & & & & \\
   & & & & & & & & & \\
   & & & & & & & & & \\
   5V & - & 100 & 3 & 10 & -3V & 0 & 0 \\
\end{array} \]

KCL: \[ I_1 + I_2 = I_3 \]
KVL: \[ 5 - 100 I_1 = 0 \quad I_1 = 0.05A \]
\[ 5 - 10 I_2 - 3 = 0 \quad I_2 = 0.2A \]

\[ \frac{dV_c}{dt} = \frac{I_1}{C} = \frac{0.5}{3} \]  
At steady state, \( I_1 = 0 \), \( V_c = 5V \).

3. Voltage test: put leads at B and C
   Current test: put leads at C and D and cut the circuit between C and D, so current flows through multimeter.

Power by source: \( I_1 V \)
Power dissipated by \( R_2 \): \( I_2^2 R_2 = I_2^2 R_2 \)
4. Approximately plot the current through the diode as a function of the voltage across the diode.

\[ V = -0.7 \text{ V} \]  
\[ V_L = -0.7 \text{ V} - (0.2 \text{ A})(50 \text{ } \Omega) = -10.7 \text{ V} \]
\[ L \frac{dI}{dt}, \text{ so } \frac{dI_1}{dt} = -5.35 \text{ A/s}. \]

5. **KCL:** \[ I = I_1 + I_2 \]

**KVL:** \[ 10 - \frac{dI_1}{dt} - 50I_1 = 0 \]

\[ 10 + V_D = 0 \]
\[ V_D \text{ is } 0.7 \text{ V if } I_2 < 0, \text{ and anything less than } 0.7 \text{ V if } I_2 = 0. \text{ (} I_2 \text{ cannot be }>0) \]

When the switch is closed for a long time, case analysis shows \( I_2 = 0 \). In steady state, inductor is a short circuit, so
\[ I_1 = \frac{10}{50} = 0.2 \text{ A}. \text{ Inductor energy } = \frac{1}{2} LI^2 = 0.04 \text{ J}. \]

When switch opens, \( I \Rightarrow 0 \), \( I_1 \) is unchanged (inductor’s current can’t change instantly), so
\[ I_2 = -I_1 = -0.2 \text{ A}. \text{ Diode is forward biased.} \]
\[ V_A = -0.7 \text{ V}. \text{ So } V_L = -0.7 \text{ V} - (0.2 \text{ A})(50 \text{ } \Omega) = -10.7 \text{ V} = L \frac{dI}{dt}, \text{ so } \frac{dI}{dt} = -5.35 \text{ A/s}. \]

6. Transistor off: \( V_{in} < V_{BE} \)

saturated when \( V_E = V_S - V_{CESat}, \text{ or } V_B = V_S - V_{CESat} + V_{BE} \).

So \( I_E = \frac{V_S - V_{CESat}}{R_2} \). A transition from \( V_{in} \) linear to saturated, \( I_B = \frac{I_E}{\beta}, \text{ and } I_E = I_C + I_B \).

Solving, get \( I_B = \frac{V_S - V_{CESat}}{R_2 (\beta + 1)} \), and saturated if \( V_{in} \geq V_S - V_{CESat} + V_{BE} + I_B R_1 \).
\[ V_B = 0.7V, \text{ at saturation, } V_c = 0.2V. \]

7. So \[ I_c = \frac{V_s - 0.2V}{R_2} = \beta I_B = \beta \frac{V_{in} - 0.7V}{R_1} \]

\[ \beta = \frac{R_1(V_s - 0.2V)}{R_2(V_{in} - 0.7V)} \]

\[ \beta \text{ must be at least this large for } \]

saturation.

8. Steady state, \( L \) is a short circuit, \( V_D \) diode is reverse biased (no current).
\[ V_c = V_{CEsat}, I_c = \frac{V - V_{CEsat}}{R_2} = \beta I_B = \beta \left( \frac{V_{in} - V_B}{R_1} \right) \]

Solving for \( V_{in} \), get \( V_{in} = V_B + \beta \frac{V_{CEsat}R_1}{R_2} \)

for saturation.

When \( V_{in} \) set to zero, transistor turns off, current must flow through diode as shown.

Current through inductor is still \( (V - V_{CEsat})/R_2 \), but begins to drop. \( V_L - IR_2 - \Delta \text{sat} = V_D = 0 \).

Find \( V_L \) from that. Then use \( V_L = L \frac{dI}{dt} \) to find \( \frac{dI}{dt} \).

\[ \downarrow \text{ must be negative by the sign convention.} \]

9. Current flows (transistor + LED on) for \( V_{in} > 1.4V \) (voltage divider).

At saturation, \( V_c = (10 - 0.7)V = 9.3V, V_e = 9.3 - 0.2 = 9.1V, \)

so \( I_E = \frac{9.1V}{100\Omega} = 0.091A = I_c + I_B = 101I_B. \)

\[ I_B = 0.9mA, V_B = 9.1V + 0.7V = 9.8V. \]

\[ V_{in} = (I_2 + I_B)1000\Omega + 9.8V, \text{ so } I_2 = \frac{9.8V}{1000\Omega} = 9.8mA. \]

Solving, \( V_{in} = (10.7mA)1000\Omega + 9.8V = 20.5V \)

10. When current flows, \( V_{out} = -0.7V \).

When current doesn't flow, \( V_{out} = V_{in} \).
11. You can build a simple 3-bit digital-to-analog converter (DAC) using an op-amp as shown at right. The input voltages take values of either 0 or 1 V and represent a 3-bit binary number. At the output you want an analog representation of the 3-bit number. \( V_{\text{out}} = -4V_2 - 2V_1 - V_0 \). What resistances \( R_0, R_1 \), and \( R_2 \) should you use? (Note: real DACs are not made this way.)

**Negative feedback, so** \( V_A = V_B = 0 \).

**No current flows in or out of op-amp inputs,** so

\[
I_0 + I_1 + I_2 = 0
\]

\[
I_0 = \frac{V_0}{R_0} \quad V_{\text{out}} = \frac{V_A}{R} \left( \frac{V_0}{R_0} + \frac{V_1}{R_1} + \frac{V_2}{R_2} \right)
\]

\[
I_1 = \frac{V_1}{R_1}
\]

\[
I_2 = \frac{V_2}{R_2}
\]

**12. In the circuit below, give** \( V_{\text{out}} \) **as a function of** \( V_1, V_2, R_1, R_2, R_3, \) **and** \( C \) **(or some subset of these).**

**No current in or out of inputs,** so \( V_B = I_2 R_2 = 0 \).

**Negative feedback, so** \( V_A = V_B = 0 \).

**No current into - terminal,** so \( I_2 = I_1 + I_C \).

\[
V_{\text{out}} = V_A - I_2 R_2 = -(I_1 + I_C) R_2
\]

\[
I_1 = \frac{V_1}{R_1}
\]

\[
I_C = C \frac{dV_2}{dt}
\]

13. In the circuit at right, give \( V_{\text{out}} \).

**Negative feedback, so** \( V_A = V_B \).

**No current into + input,** so \( V_B = V_2 \).

\[
I = \frac{V_1 - V_A}{R} = \frac{V_1 - V_2}{R}
\]

\[
V_{\text{out}} = V_A - V_C = V_B - V_C = V_2 - V_C
\]

\[
V_C = \frac{1}{C} \int I \, dt = \frac{1}{C} \int \left( \frac{V_1 - V_2}{R} \right) \, dt
\]