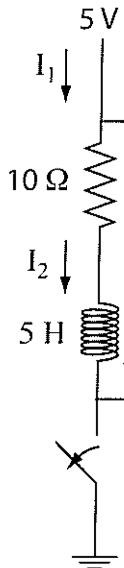
ME 333 Introduction to Mechatronics
Winter 2011
Circuits Quiz

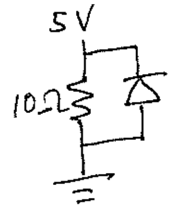
Name: Solutions

No books, calculators, computers, notes, etc. Just a pen or pencil. Show your work to receive full credit. If you can't do a particular calculation without a calculator, such as $\sqrt{12.2}$, feel free to leave the mathematical expression without simplifying. Similarly, feel free to leave fractions.

1. Consider the circuit below. The switch has been closed (conducting) for a long time. The forward bias voltage of the diode, when it is conducting, is 0.7 V. According to the arrows shown (current is positive if it flows in the direction of the arrow), what are the currents I_1, I_2, and I_3 with the switch closed? Be sure to give the proper signs and units.



inductor is a short circuit in steady state



so $I_1 = \frac{5\text{ V}}{10\,\Omega} = 0.5\text{ A}$

$I_2 = I_1 = 0.5\text{ A}$

$I_3 = \emptyset\text{ A}$

Now the switch is opened. Immediately after the switch is opened, what are the currents I_1, I_2, and I_3? According to the sign convention shown for the inductor voltage V_L, what is the voltage across the inductor right after the switch is opened? What is the rate of change of the current through the inductor, dI_2/dt? For all answers, give signs and units.

I_1: 0 A

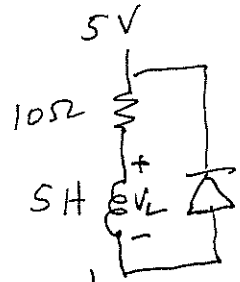
I_2: 0.5 A

I_3: −0.5 A

V_L: −5.7 V

dI_2/dt: $-\frac{5.7}{5}$ A/s

Current through the inductor does not change discontinuously. Circuit becomes



$\downarrow I_3 = -0.5\text{ A}$ → current flows through diode

$I_1 = 0\text{ A}$

$\hookrightarrow I_2 = 0.5\text{ A}$

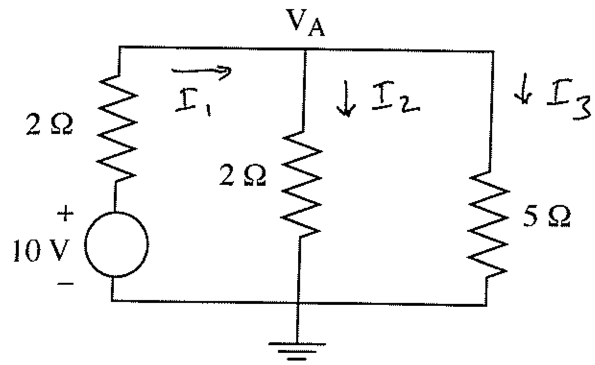
diode drop

KVL: $0 = (0.5\text{ A})(10\,\Omega) + V_L + 0.7\text{ V}$

$V_L = -5.7\text{ V} = L\frac{dI_2}{dt}$

$\frac{dI_2}{dt} = \frac{-5.7\text{V}}{5\text{H}} = \frac{-5.7}{5}\text{ A/s}$

2. For the circuit shown below, give the voltage V_A, the current provided by the 10 V battery, and the power provided by the battery. Give units.



KCL: $I_1 = I_2 + I_3$

KVL: $10 - 2I_1 - 2I_2 = 0$

$10 - 2I_1 - 5I_3 = 0$

Solve these 3 linear equations in 3 variables to get

$I_1 = \frac{35}{12}$ A, $I_2 = \frac{25}{12}$ A, $I_3 = \frac{5}{6}$ A

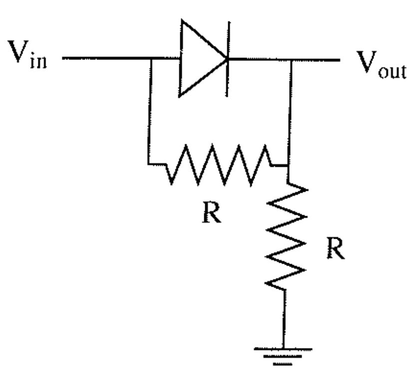
$V_A = 2I_2 = 5I_3 = \frac{25}{6}$ V

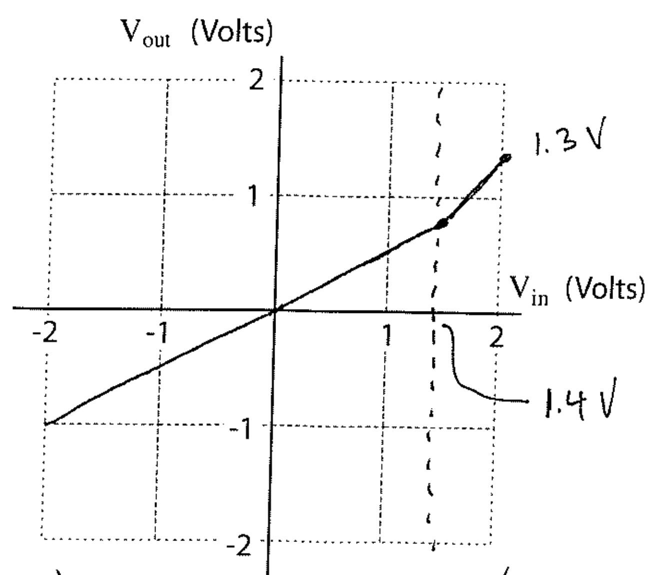
V_A: $\frac{25}{6}$ V

current: $I_1 = \frac{35}{12}$ A

power: $(10\text{ V})\, I_1 = \frac{175}{6}$ W

3. In the circuit below, plot the voltage V_{out} as a function of the input voltage V_{in}, where V_{in} takes values between -2 V and 2 V. The diode drop is 0.7 V when it is conducting current.

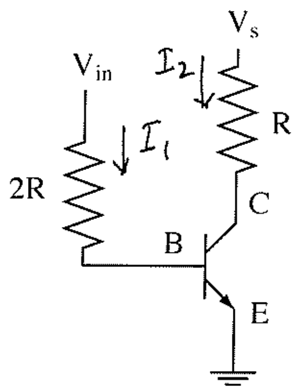




diode does nothing; voltage divider

diode turns on, keeps $V_{out} = V_{in} - 0.7$ V

4. In the circuit below, the gain of the npn bipolar junction transistor is β when it is in the linear regime. When the transistor is on, the voltage drop from the base B to the emitter E is V_{BE}. When the transistor is saturated, the voltage drop from the collector C to the emitter E is V_{CE}. Using this information, find the range of voltages V_{in} where the transistor is off; the range of voltages V_{in} where the transistor is in its linear regime; and the range of voltages V_{in} where the transistor is saturated. Your answers should be in terms of (some subset of) V_s, β, R, V_{BE}, and V_{CE}.



V_{in} range where transistor is off: $V_{in} < V_{BE}$

V_{in} range where transistor is in linear regime: $V_{BE} \le V_{in} < \frac{2}{\beta}(V_s - V_{CE}) + V_{BE}$

V_{in} range where transistor is saturated: $V_{in} \ge \frac{2}{\beta}(V_s - V_{CE}) + V_{BE}$

transition point between linear & saturated:

$$R I_2 + V_{CE} = V_s$$

$$I_2 = \beta I_1$$

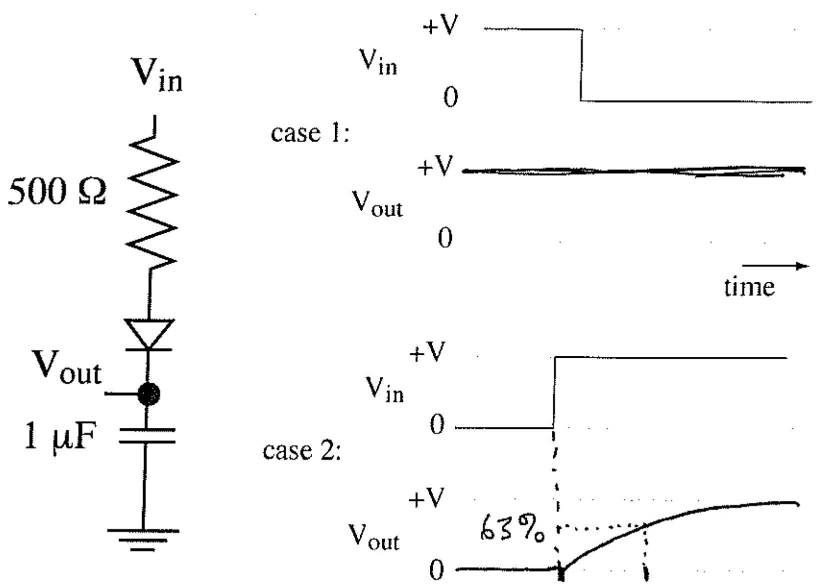
$$I_1 = \frac{V_{in} - V_{BE}}{2R} \Rightarrow \text{so } R\beta\left(\frac{V_{in} - V_{BE}}{2R}\right) + V_{CE} = V_s$$

$$V_{in} - V_{BE} = \frac{2}{\beta}(V_s - V_{CE})$$

$$V_{in} = \frac{2}{\beta}(V_s - V_{CE}) + V_{BE}$$

larger values : saturated
smaller values: linear

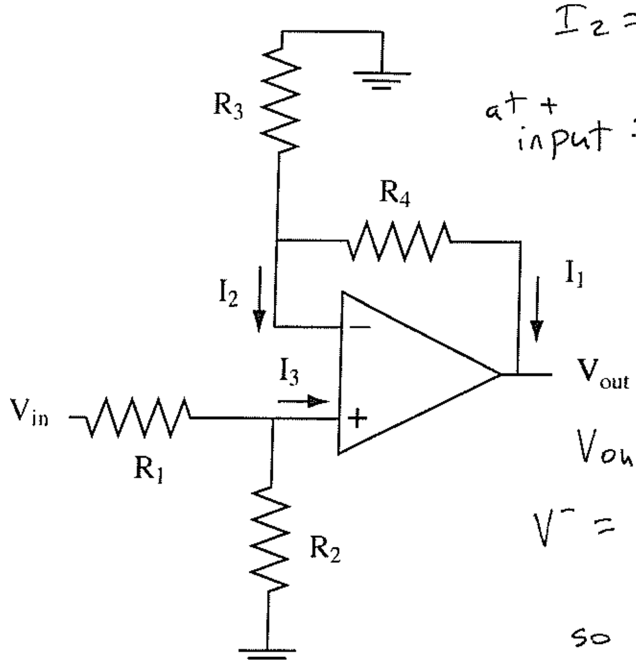
5. (In this problem, the forward bias voltage of the diode is 0 V when it is conducting.) Consider the circuit below. In one case, V_{in} has been held at a positive value for a long time, and then it drops to 0 V. In the other case, V_{in} has been held at 0 V for a long time, and then switches to a positive value. Approximately plot V_{out} for each case. Put a numerical time scale on your plots.



diode does not let the capacitor discharge. Time scale is irrelevant.

$$\Delta t = RC = (5\times10^{2})(1\times10^{-6}) = 5\times10^{-4}\,s$$

6. In the circuit below, find I_1, I_2, I_3, and V_{out} as a function of V_{in}, R_1, R_2, R_3, and R_4.



$I_2 = I_3 = 0$ by property of op amp

at + input: $V^+ = V_{in}\dfrac{R_2}{R_1+R_2}$ solve voltage divider

Because of negative feedback,

$$V^- = V^+ = V_{in}\frac{R_2}{R_1+R_2}$$

$$V_{out} = -I_1(R_3+R_4)$$

$$V^- = -I_1R_3 = \frac{V_{in}R_2}{R_1+R_2}$$

so $$I_1 = -\frac{V_{in}R_2}{R_3(R_1+R_2)}$$

$$V_{out} = \frac{V_{in}R_2(R_3+R_4)}{R_3(R_1+R_2)}$$