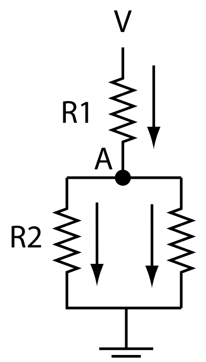
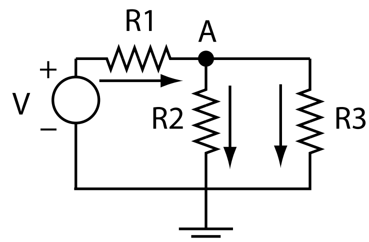
ME 333 Introduction to Mechatronics
Circuits Review Questions

1. You should recognize that the two circuits below are identical, just drawn slightly differently. The circle is a voltage source of V volts. When you are asked the voltage at a point, it is in reference to ground (GND), which is 0 volts by definition.

In terms of V, R1, R2, and R3, what is the voltage at A? What is the current through R1, R2, and R3? (Note, current is "positive" if it is flowing in the direction of the arrows shown, and "negative" otherwise.) How much power is provided by the voltage source? How much power is dissipated by resistor R2?

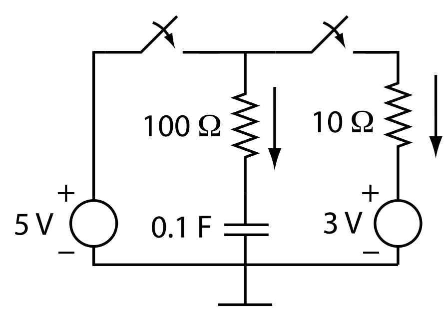




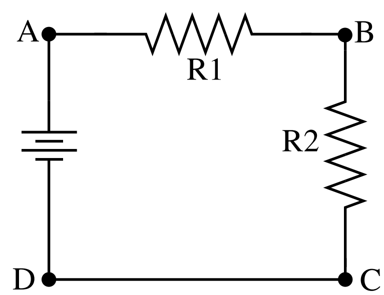
2. Assume the capacitor is initially discharged (0 volts across it), and both switches, which are initially open, are closed at time t = 0.

Just after the switches are closed, what is the current through each resistor? What is the rate of charging of the capacitor, in volts per second?

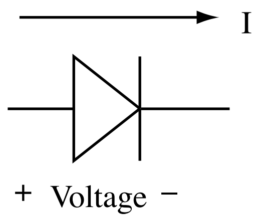
After the circuit reaches steady state, what is the voltage across the capacitor? How much energy has it stored? In steady state, is the 3V battery being charged or discharged, and at what rate (how much power is being provided or dissipated/stored)? How about the 5V battery? Give units for all your answers (amps, volts, watts, joules). Plot, by hand, the voltage across the capacitor as a function of time, starting at t = 0. Note that after one time constant, the capacitor should have charged to 63% of its final value.

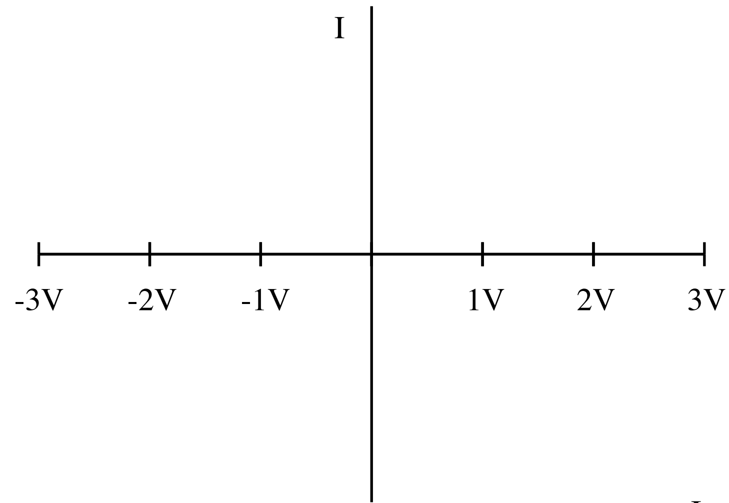


3. You wish to use a multimeter to measure the current through R2 and the voltage across R2. You may place your test leads at any of A, B, C, and D, and you may break the circuit anywhere, if needed. To measure the voltage across R2, you set the multimeter to voltage testing mode, and then do what? To measure the current through R2, you set the multimeter to current testing mode, and then do what?

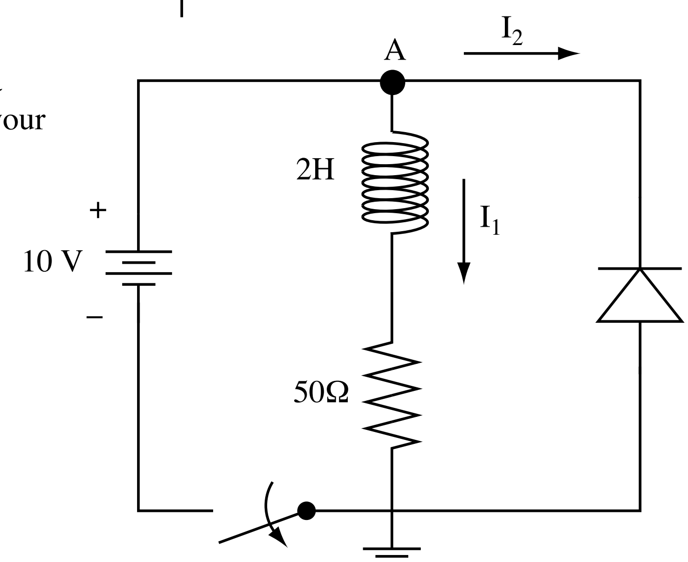


4. Approximately plot the current through the diode as a function of the voltage across the diode.



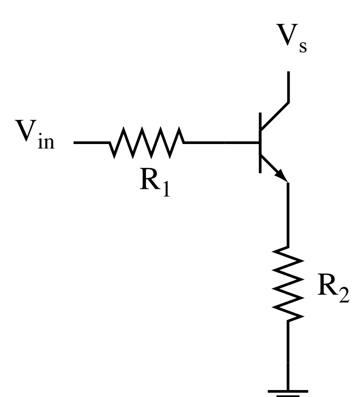


5. The switch in the circuit at right has been closed for a long time, so that the circuit is in steady state. In all of your answers, make sure that the **sign** of the current is correct. All of your answers should be numbers with **proper units**. Assume that the forward bias voltage of the diode is 0.7 V.

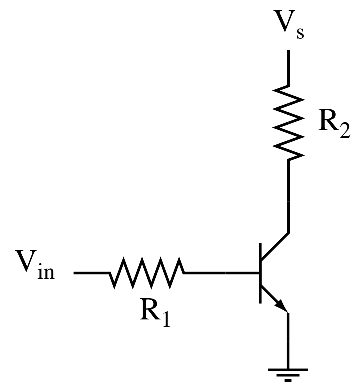


a. Give the steady-state current I_1.
b. Give the steady-state current I_2.
c. What is the energy in the inductor?
d. The switch is now opened at t=0. What is I_1 the instant after the switch is opened?
e. At the instant after the switch is opened, what is I_2?
f. At the instant after the switch is opened, give the voltage at point A (referenced to ground).
g. At the instant after the switch is opened, give the rate of change of I_1 (that is, dI_1/dt).
h. Plot the voltage across, and current through, the inductor as a function of time from t=0. The plots should clearly show the time constant.

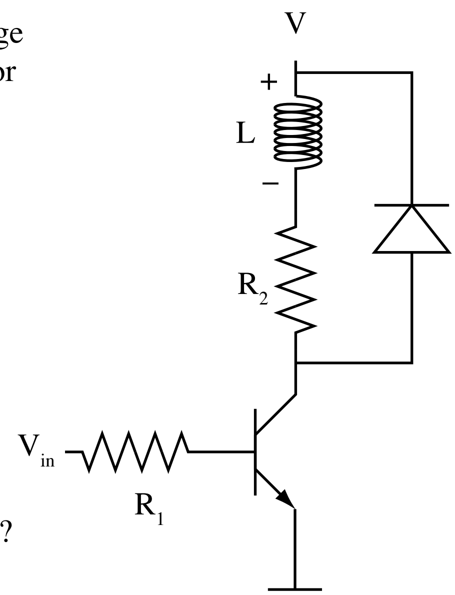
6. For the transistor below, the voltage from the base to the emitter is V_{BE} when the transistor is on, and when the transistor is saturated, the voltage from the collector to the emitter is V_{CEsat}. In the linear (active) mode, the transistor satisfies $I_C = \beta I_B$, where β is the transistor gain. Give the ranges of V_{in} voltages for which the transistor is off and for which it is saturated.



7. If this transistor is in saturation, what is a lower bound on its gain β? (Remember $I_C = \beta\, I_B$ when the transistor is in active mode.) Assume that the voltage from the collector to emitter is $V_{CEsat} = 0.2$ V in saturation, and the voltage from the base to the emitter is $V_{BE} = 0.7$ V when the transistor is on. These are common approximations we will make in this class.



8. Consider the circuit at right. The transistor gain is β, the base-emitter voltage when the transistor is on is V_{BE}, the collector-emitter voltage when the transistor is saturated is V_{CEsat}, and the forward bias voltage of the diode is V_D. All answers for this problem should be in terms **only** of some subset of these four values, V, and the resistances and inductance indicated at right.



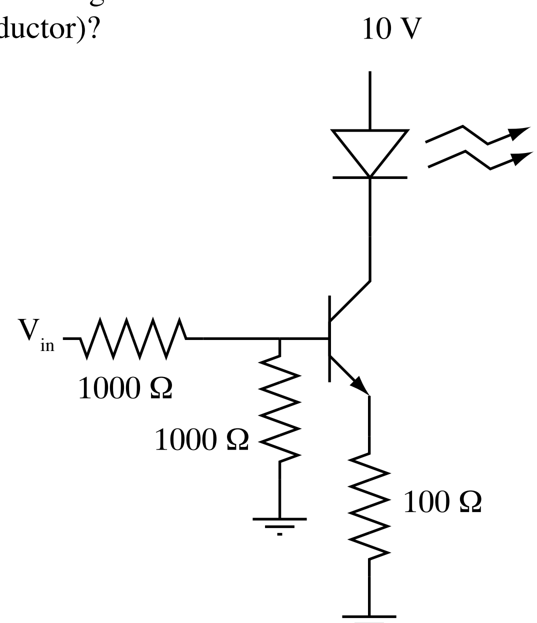
a. For what voltages of V_{in} is the transistor saturated in steady state (i.e., the current through the inductor is not changing)?

b. Assume that the transistor has been saturated for long time, and then V_{in} is suddenly set to zero. Clearly indicate on the circuit diagram the full current path after this switch.

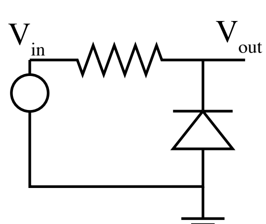
c. In the instant after V_{in} is set to zero, what is the current through the inductor?

d. In the instant after V_{in} is set to zero, what is the voltage across the inductor? Is the voltage positive or negative, according to the sign convention in the diagram (positive voltage means that the voltage is higher at the "top" of the inductor)?

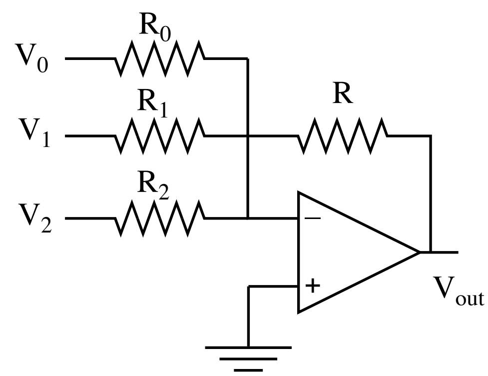
9. Calculate the voltage range for V_{in} for which the LED is off and for which the LED is at its maximum brightness in the circuit at right. The transistor gain is 100. Assume the diode drop and V_{BE} when the transistor is on is 0.7 V and V_{CEsat} is 0.2 V. (**Note**: a better approximation for the LED drop is about 1.7 V.)



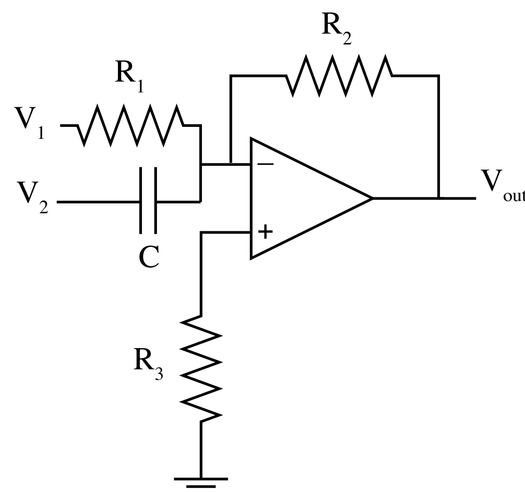
10. Plot the output voltage for the circuit below if the input voltage is a sine wave from -5 V to 5 V.



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, $V_{out} = -4V_2 - 2V_1 - V_0$. What resistances R_0, R_1, and R_2 should you use? (Note: real DACs are not made this way.)



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



13. In the circuit at right, give V_{out}.