Midterm Practice (optional, but similar problems will be on the midterm). Solutions available in office hours and on bspace 9/18/2012.

Midterm:

- In-class (check bspace for room assignment)
- Open-book, 1 page of handwritten notes
- No calculators (or other electronic devices)
- Topics: lectures up to 9/13/2012 & homework up to and including this one
- Midterm and all future assignments: unless otherwise specified, assume that circuits are at room temperature.
- In EE105 (and life?): do something sensible if a problemset fails to include the five pages of legalese and mind-numbing definitions that seem to accompany just about everything else we do or need in life.

1. a) Design a piece of Silicon with $n = 500\,\text{cm}^{-3}$ at 300K. Be specific and quantitative!
   b) Calculate the current density for $E = 100\,\text{V/m}$.

2. In the two circuits shown below, V_B and R_B are adjusted such that $I_o1 = I_o2 = I_o = 1\,\text{mA}$ at 300 K for the following nominal parameters: $V_{CC} = 5\,\text{V}$, $R_{L1} = R_{L2} = R_L = 1\,\text{k}\Omega$, and $I_s = 10\,\text{fA}$, $\beta \to \infty$, $V_A \to \infty$ for all transistors. Also $dV_{BE(on)}/dT = -2\,\text{mV/C}$.

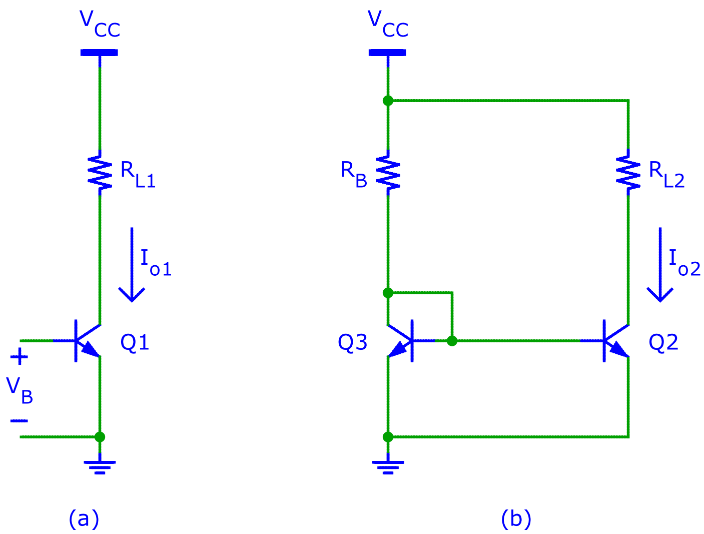
   Now the temperature, supply voltage, load resistance and transistor parameters change as specified in the table below. Assuming V_B and R_B are kept constant, calculate the relative change of the currents I_{o1} and I_{o2} from their nominal value, $I_o = 1\,\text{mA}$.

T	V_{CC}	R_L	I_s	β	V_A	$\frac{I_{o1}}{I_o} - 1$ [%]	$\frac{I_{o2}}{I_o} - 1$ [%]
300 K	5 V	1 kΩ	10 fA	∞	∞	0 %	0 %
300 K	5 V	2 kΩ	10 fA	∞	∞		
300 K	6 V	1 kΩ	10 fA	∞	∞		
240 K	5 V	1 kΩ	10 fA	∞	∞		
360 K	5 V	1 kΩ	10 fA	∞	∞		
300 K	5 V	1 kΩ	20 fA	∞	∞		
300 K	5 V	1 kΩ	10 fA	50	∞		
300 K	5 V	1 kΩ	10 fA	∞	50 V		

   What are these circuits useful for? What "ideal" circuit element do they resemble to? Which version, (a) or (b) is preferable and why?

   This circuit (especially the one on the right) is a core building block used in many more complicated circuits (operational amplifier, A/D converters, etc.). You will use it frequently in your designs and recognizing it will help you understand circuit operations without resorting to long calculations.

   Note: specify answers to 5 % accuracy. Keeping this in mind lets you avoid lots of senseless nonlinear equation solving.

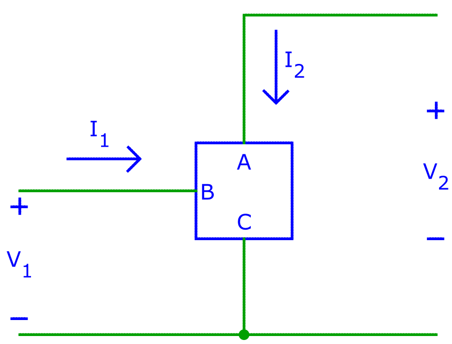


3. Your friend is a device physicist (took EE130). After a sleepless night solving incredibly complicated nonlinear equations (how we appreciate *linear* small-signal models!) he found the following expressions for the large-signal behavior of his new device:

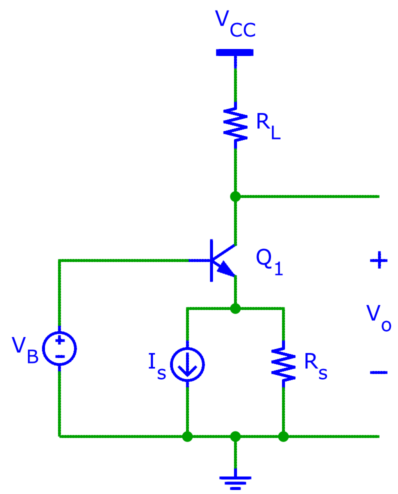
$$V_1 = R_1 I_1$$
$$I_2 = \alpha I_1 \left(1 + \frac{V_2}{V_X}\right)^2$$

In the lab, he measured $V_X = 1\,\text{V}$, $\alpha = 100$ and $R_1 = 100\,\text{k}\Omega$.

Draw the small-signal model calculate and mark all component values in the schematic. Indicate terminals A, B, and C, voltages v_1 and v_2 and currents i_1 and i_2 in the small-signal model.



4. In the circuit below $V_B = 5\,\text{V}$, $V_{CC} = 10\,\text{V}$, $R_L = 10\,\text{k}\Omega$, $R_s = 5\,\text{k}\Omega$, $I_s = 10\,\text{fA}$, $\beta = 100$, $V_A = \rightarrow \infty$ (optional: $V_A = 100\,\text{V}$). The source $I_s = I_S + i_s$ is the sum of bias current $I_S = 260\,\mu\text{A}$ and (small-signal) signal current i_s.
   a) Draw the small-signal model.
   b) Calculate the small-signal transresistance $r_x = v_o / i_s$.
   c) Calculate the small-signal transresistance r_x for $R_s = 10\,\text{k}\Omega$.
   d) Calculate the small-signal transresistance r_x for $R_s = 5\,\text{k}\Omega$ and $R_s = 10\,\text{k}\Omega$ assuming the transistor was not present, i.e. its collector and emitter are shorted together and V_B is disconnected.
   e) Some sensors (e.g. photodiodes) behave like current sources, albeit with a relatively low and not accurately known output resistance R_s. Explain how this circuit is useful for this type of sensor.



5. Digital-to-analog converters (DACs) are used e.g. in music players to convert digital MP3 files to analog voltages for rendering with a headset or speaker. You are to design a DAC that converts a binary 8-bit number (0 . . . 255 decimal) to a current (0 . . . 255 μA) in equal steps.

   Available components: ideal switches (controlled by binary signals), transistors, resistors, a supply (3 V $\pm$ 10 %) and one ideal current source $I_B = 16\,\mu$A.