Due in the "EE 105 box" near 125 Cory Hall by 5pm on Friday 9/7/2012.

Read Sections 3.1–2,5 and 4.1–3 in B. Razavi: Fundamentals of Microelectronics

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

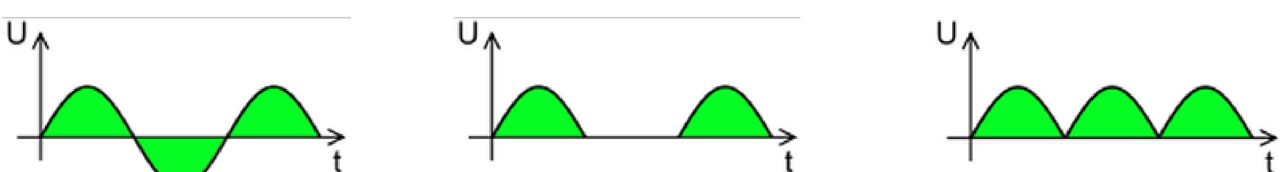
2. a) Design a diode with built-in potential $V_0 = 800\,\text{mV}$ at room temperature. Note: this problem has more than one correct solution.
   b) What is the value of V_0 at 85 C?

3. a) Your design needs a diode with $I_s = 3\,\text{fA}$. In your drawer you find only diodes with $I_s = 1\,\text{fA}$. Design a circuit that emulated the required diode with what is available.
   b) Explain what's wrong with circuit designs that depend on the value of $I_s = 3\,\text{fA}$.
   So much for your effort in part (a) . . .

4. Plot (you now know how!) the voltage V_D across a diode versus the forward current I_D for $I_s = 1\,\text{pA}$. Scale: vertical axis: 0.1 . . . 1 V logarithmic, horizontal axis: 0 . . . 1 A linear.
   a) What is the value of $V_{D,on}$.
   Do not forget you are an engineer, not a mathematician. You know (and soon will be paid to know) when it makes sense to use a reasonable approximation—and when not.
   b) Design a diode with $V_D = 750\,\text{mV}$ at $I_D = 500\,\text{mA}$.

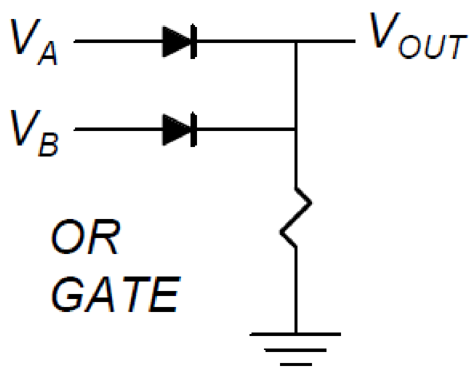
5. Given is a 10 V peak, 60 Hz sinusoidal source (voltage shown in part (a) of the figure below). E.g. the power line voltage is sinusoidal.
   a) Design a circuit that puts the voltage shown in part (b) of the figure across a 1 kΩ resistor.
   b) Same, but for the voltage waveform shown in part (c). Presumably this problem has many solutions; submit the one that requires the fewest components.
   c) Same, but with the additional constraint that the voltage across the resistor is not allowed to drop by more than 100 mV from its peak value (in steady state). Specify all component values.
   This is the circuit used in old wall transformers. Modern power bricks are more sophisticated.

   Available components: diodes (ideal), resistors, capacitors, inductors.

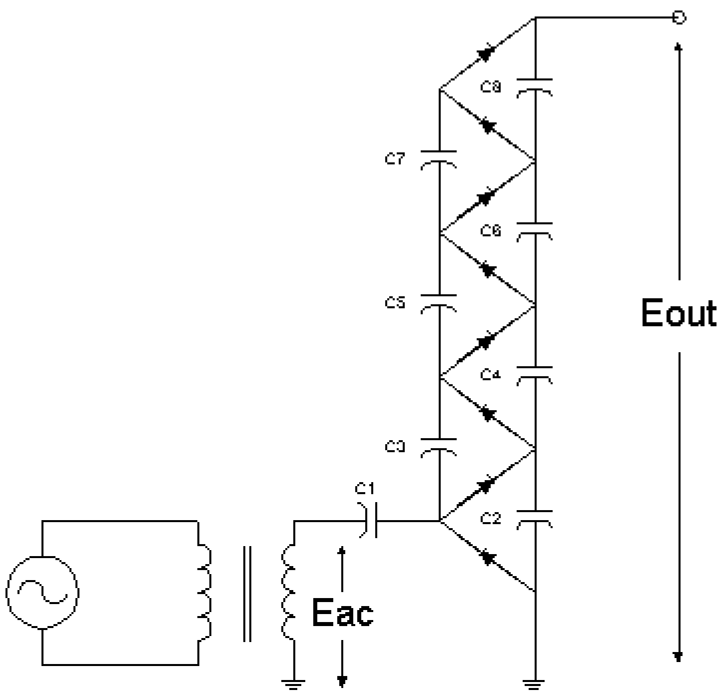


(a) (b) (c)

6. Convince yourself that the circuit shown below implements an OR gate (either of the inputs V_A or V_B pulls the output V_{OUT} high.
   a) Design an AND gate using only diodes and resistors.
   b) Cascade the AND and OR gate to realize $Y = A + BC$.
   c) Would the same approach work for cascades of many (more than two) logic gates? Why not?



7. In the circuit below is called a CockcroftâĂŞWalton generator. The circuit has many uses e.g. in particle accelerators or X-ray equipment. It is driven by a sinusoidal voltage source E_{ac} with amplitude 10 V. The value of all capacitors is very large and the diodes are ideal.
   a) What is the value of voltage E_{out}?
   b) Explain a modification that generates 1 MV from a 10 V source.



8. Design a voltage reference that outputs $V_{\text{ref}} = 1.4\,\text{V} \pm 5\,\%$ over the commercial temperature range (0 C … 70 C).
   Available components: a 3.3 V ± 20 % supply, resistors (specify value), and diodes (specify I_s). Verify that your circuit meets the specification by hand analysis and with SPICE at 0 C, 20 C, and 70 C. For simplicity you may assume that the load current (current delivered to whatever is connected to the reference) is zero. Can all the requirements be met?
   This problem has more than one correct solution! Choose one that minimizes power dissipation and component count.