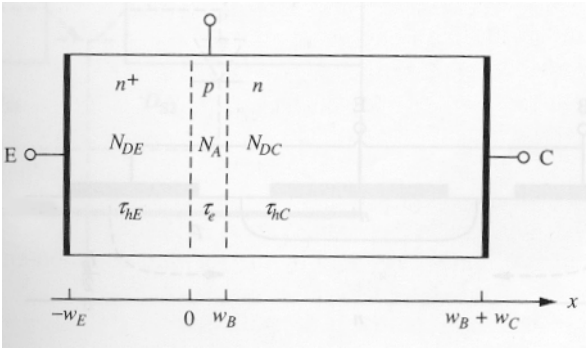
http://www.ece.umd.edu/~pabshire/enee312h.htm due Tuesday, March 19, 2002

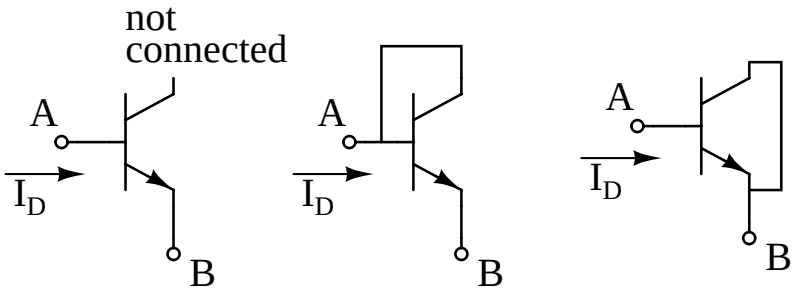
1) The *npn* silicon transistor shown below is characterized by the following parameters:
$N_{DE} = 5x10^{17}$ cm^{-3}, $w_E = 3\ \mu$m, $\tau_{hE} = 0.1\ \mu$s, $\mu_{hE} = 250$ cm^2/Vs
$N_{AB} = 5x10^{16}$ cm^{-3}, $w_B = 0.8\ \mu$m, $\tau_{eB} = 0.1\ \mu$s, $\mu_{eB} = 1000$ cm^2/Vs
$N_{DC} = 5x10^{15}$ cm^{-3}, $w_C = 6\ \mu$m, $\tau_{hC} = 0.1\ \mu$s, $\mu_{hC} = 500$ cm^2/Vs
Start by checking whether the lengths w are small compared to the diffusion lengths, and use these results to compute the effective lengths w^*. The active cross-sectional area of the transistor is $5x10^4$ cm^2. Use $V_T = kT/q = 0.025$V and $n_i = 10^{10}$ cm^{-3}.



   a. The transistor is operated in the forward active mode with $V_{BE}>0$ and $V_{BC}=0$. Obtain numerical values for the base and emitter defects, δ_{EF} and δ_{BF}.
   b. The transistor is operated in the reverse active mode with $V_{BC}>0$ and $V_{BE}=0$. Obtain numerical values for the base and collector defects, δ_{CR} and δ_{BR}.
   c. Obtain numerical values for β_F and β_R.
   d. Obtain numerical values for the parameters of the Ebers-Moll model: I_{ES}, I_{CS}, α_F and α_R.
   e. Show that $\alpha_F I_{ES} = \alpha_R I_{CS}$.

2) Two high-gain bipolar transistors have identical dimensions and identical emitter, base, and collector doping profiles, except that transistor A is *npn* and transistor B is *pnp*. Indicate which device, if either, has the properties stated below and explain why.
   a. Largest forward current gain β_F
   b. Smallest transconductance g_m with $|I_C| = 1$mA
   c. Largest base-collector diode saturation current I_{CS}
   d. Lowest parasitic base resistance r_x

3) Consider using the emitter-base junction of an *npn* transistor as a diode. We want to compare the three possible connections illustrated below.



a. Find a relationship for the diode current I_D as a function of V_{AB} in terms of the Ebers-Moll parameters I_{ES}, I_{CS}, α_F and α_R of the transistor.
b. For which of these "diodes" is the saturation current "I_S" the smallest? The largest?
c. For each of these connections find expressions in terms of the Ebers-Moll parameters for the ratio of the collector current to the emitter current.
d. Indicate on sketches of each of the connections the main current path through the device from A to B.

4) – 7) Complete Sedra & Smith problems 4.3, 4.5, 4.10, 4.97

Research Question:
What is the Early effect? Perform a literature search to find the original paper (nearly 50 years old!) in which Jim Early provides a quantitative explanation and model for the phenomenon. Read the paper and comment on his explanation.