1. An npn transistor has neutral region widths of $x_E = 0.2\mu m$, $x_B = 0.1\mu m$ and $x_C = 0.5\mu m$, and doping of $N_{dE} = 5 \times 10^{19} cm^{-3}$, $N_{aB} = 2 \times 10^{18} cm^{-3}$ and $N_{dC} = 10^{17} cm^{-3}$. Assume that in all regions the minority carrier lifetimes are $0.5\mu s$.

   (a) Determine α_F (I_C/I_E) for forward operation (base-emitter junction forward biased, base-collector junction unbiased or reverse biased). Assume that recombination in the base and in the depletion regions can be ignored ($\alpha_F = \gamma_F$). Use this value to determine β_F.

   (b) Determine α_R (I_E/I_C) for reverse operation (base-emitter junction unbiased or reverse biased, base-collector junction forward biased). Assume that recombination in the base and in the depletion regions can be ignored ($\alpha_R = \gamma_R$). Use this value to determine β_R.

   (c) For the bias conditions of (a) and (b), sketch the minority charge densities and current densities as functions of position from emitter to collector. Assume the diode which is off is reversed biased by at least a few kT.

2. For an npn transistor with $\alpha_F = 0.995$, $\alpha_R = 0.2$ and $I_{ES} = 10^{-17}$ A (10 aA), use the Ebers-Moll model to:

   (a) Find the collector current (I_C) if $I_B = 1\mu A$ and $V_{CE} = 3$ V.

   (b) Find the collector to emitter voltage (V_{CE}) if $I_B = 10\mu A$ and $I_C = 100\mu A$.

   In each case, estimate whether the base-emitter and base-collector junctions are forward or reverse biased and use that information to help simplify the analysis if possible. (Diode reverse leakage current can generally be neglected.)