Problem 1

You are given an npn bipolar transistor which has uniform doping concentrations $N_{dE} = 10^{19} \text{ cm}^{-3}$, $N_{aB} = 10^{17} \text{ cm}^{-3}$, $N_{dC} = 10^{16} \text{ cm}^{-3}$. Assume the base width is 1 $\mu$m from the B-E junction to the B-C junction. The area of the emitter and collector is 10$^{-6}$ cm$^2$, $\mu_n = 1000 \text{ cm}^2/\text{V-sec}$, $\mu_p = 500 \text{ cm}^2/\text{V-sec}$. Ignore the depletion region width of forward biased junctions.

### Emitter Base Collector

- $W_E$ - 0 - 1 $\mu$m - $W_C$

1 $\mu$m - $x_p$ - 1 $\mu$m + $x_n$

\text{a)} Given $V_{BE} = 0.66\text{V}$ and $V_{BC} = -3\text{V}$ sketch the minority carrier concentration vs. $x$ in all three regions of the device.

\text{b)} Calculate $x_n$ and $x_p$ at the base-collector junction.

\text{c)} Find the emitter width $W_E$ such that $\beta_F = 200$.

\text{d)} Find the collector width $W_C$ such that $\beta_R = 5$.

\text{e)} Calculate $I_S$
Problem 2

You are given the npn transistor with the parameters and operating point from Problem 1 above, with the additional information that $V_{an} = 20$V.

a) Find the transconductance, $g_m$

b) Find the input resistance, $r_\pi$

c) Find the output resistance $r_o$

d) What is the minority electron storage $Q_{NB}$?

e) Find $C_\pi$

f) At what frequency does $|1/j\omega C_\pi| = r_\pi$?

Problem 3

Silicon-Germanium bipolar transistors were developed in the late 1980’s to improve the current gain $\beta_F$ over that of conventional silicon transistors. When the emitter is made of this material we can assume that the intrinsic carrier concentration in the emitter is reduced to $10^9$ cm$^{-3}$. This transistor is biased in the forward active region and has a collector current $I_C = 100\mu$A. Use the same dimensions and doping concentrations as Problem 1 for this problem.

a) Calculate the new $V_{BE}$ such that $I_C = 10\mu$A

b) Find the forward active current gain, $\beta_F$.

c) Determine the base doping level that will yield the same value of $\beta_F$ as the transistor would have if its emitter were silicon instead of SiGe?

Problem 4

Howe and Sodini P7.6