An n-p-n transistor has impurity concentrations of $10^{19} \text{ cm}^{-3}$, $10^{16} \text{ cm}^{-3}$ and $10^{15} \text{ cm}^{-3}$ in the emitter, base and collector regions respectively. Assume that the distance between the two metallurgical junctions, $W_{BJ}$ is $2.5 \times 10^{-4} \text{ cm}$. Assume that the emitter-base junction is forward biased to 0.5 V. Find the punch-through voltage.

2 Assume that for the device in problem 1, $\tau_B = 5 \times 10^{-8} \text{ sec}$ and the minority carrier lifetime in the base is $10^{-8} \text{ sec}$. Assume the transistor to be intrinsic. What is $BV_{CEO}$ assuming that $\gamma$ is nearly unity. Take the value of the parameter $\eta$ as 3 and $BV_{CBO}$ to be 250 V.

3 For the device in problem 2, determine $f_{ca}$, $f_{cb}$ and $f_T$. Assume the device is intrinsic i.e., you can neglect the parasitic elements and the junction capacitances.

4 Assume an area of $10^{-3} \text{ cm}^2$ for the emitter-base junction for the device in problem 1. Assume $\tau_B$ is not the value given in problem 2. Assume the width of the neutral base region $W'$ to be $\sqrt{2} \times 10^{-4} \text{ cm}$. Let the minority carrier diffusion constant in the base be $16 \text{ cm}^2 \text{ sec}^{-1}$. Calculate $f_{ca}$ and $f_{cb}$ at an emitter-base bias voltage of 0.6 V and a collector-base reverse bias of 5 V. (Note: You are still assuming that $\gamma$ is nearly unity.)

5 For the operating voltage given in the last problem determine the equivalent circuit. Assume the area of the collector-base junction to be the same as that for the emitter-base junction.

6 Assume that $V_{CC}$ is 10 V for the device in the last problem. Calculate the storage time when the device is used as an inverter with a load resistor of resistance equal to $10k\Omega$. Assume that the base current drive is 2 mA and that the current has been on for a long time for the purpose of calculating the storage time.

7 A switching transistor has the following characteristics $f_{ca} = 10^6 \text{ Hz}$ and $f_T = 10^8 \text{ Hz}$. The device is used as a saturated inverter and assume (a) $\gamma$, the emitter injection efficiency is nearly unity, b) the load resistor is $5k\Omega$ and (c) the collector supply voltage is 10 V. A base drive current of 50$\mu$A is applied at $t=0$. Calculate the time required to turn the device on.

8 In the device in problem 7 assume that the base current of 50$\mu$A is flowing for sufficiently long time to establish steady state condition. Assume that at $t=0$, the base current is switched off. Calculate the turn-off time which is defined as the time required for the collector current to decay to a predetermined fraction such as $1/2$ or 10% of the initial value.

9 For the condition given in problem 8, determine the emitter-base voltage at time $t = 0$, assuming that the device is a p-n-p transistor and the base doping is $10^{16} \text{ cm}^{-3}$.

10 The impurity concentration in the base of a n-p-n transistor is given approximately by the function

$$N_B(x') = N_{BE} \exp\left(\frac{-\eta x'}{W'}\right)$$

(1)

where $N_{BE} = \text{impurity concentration at } x' = 0$ and $\eta$ is a parameter. Take $W'$ as equal to 2 $\mu$m.

(a) What is the value of $\eta$ if $N_{BC} = N_B(x' = W') = 10^{-3} N_{BE}$. Do not confuse this $\eta$ with the one that we used to calculate $BV_{CEO}$.

(b) What is the value of the electric field in the base?