Homework 6 – sut25223

1. A uniformly doped silicon npn bipolar transistor is to be biased in the forward-active mode with the B-C junction reverse biased by 3v. The metallurgical base width is 1.10 μm. The transistor dopings are $N_E = 10^{17}$ cm^{-3}, $N_B = 10^{16}$ cm^{-3}, and $N_c = 10^{15}$ cm^{-3}. *(a)* For $T = 300$ K, calculate the B-E voltage at which the minority carrier electron concentration at x = 0 is 10 percent of the majority carrier hole concentration. *(b)* At this bias, determine the minority carrier hole concentration at $x' = 0$. *(c)* Determine the neutral base width for this bias.

2. A silicon npn bipolar transistor is uniformly doped and biased in the forward-active region. The neutral base width is .$x_B = 0.8$ μm. The transistor doping concentrations are $N_E = 5\times10^{17}$ cm^{-3}, $N_B = 10^{16}$ cm^{-3}, and $N_c = 10^{15}$ cm^{-3}. *(a)* Calculate the values of p_{E0}, n_{B0}. and p_{C0}. *(b)* For $V_{BE} = 0.625$ V, determine n_B at $x=0$ and p_E at $x' = 0$. *(c)* Sketch the minority carrier concentrations through the device and label each curve.

3. Consider a uniformly doped npn bipolar transistor at T = 300 K with the following parameters:

   $N_E = 10^{18}$ cm^{-3} $\quad$ $N_B = 5\times10^{16}$ cm^{-3} $\quad$ $N_c = 10^{15}$ cm^{-3}

   $D_E = 8$ cm^2/s $\quad$ $D_B = 15$ cm^2/s $\quad$ $D_C = 12$ cm^2/s

   $\tau_{E0} = 10^{-8}$ s $\quad$ $\tau_{B0} = 5\times10^{-8}$ s $\quad$ $\tau_{C0} = 10^{-8}$ s

   $x_E = 0.8$ μm $\quad$ $x_B = 0.7$ μm $\quad$.

   Drive equation for J_{Ep} considering x_E. For $V_{BE} = 0.60$ V and $V_{CE} = 5$ V, calculate *(a)* the currents J_{Ep} , J_{En} ,and J_{Cn} *(b)* the current gain factors γ, α_T, α, and β.

4. Three npn bipolar transistors have identical parameters except for the base doping concentrations and neutral base widths. The base parameters for the three devices are as follows:

Device	Base doping	Base width
A	$N_B = N_{B0}$	$x_B = x_{B0}$
B	$N_B = 2N_{B0}$	$x_B = x_{B0}$
C	$N_B = N_{B0}$	$x_B = 0.5\, x_{B0}$

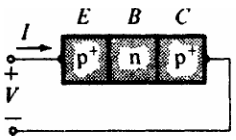
(The base doping concentration for the B device is twice that of A and C, and the neutral base width for the C device is half that of A and B.)

(*a*) Determine the ratio of the emitter injection efficiency of (*i*) device B to device A and (*ii*) device C to device A.

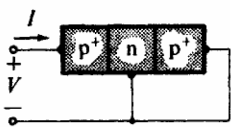
(*b*) Repeat part (*a*) for the base transport factor.

(*c*) Which device has the largest common-emitter current gain β?

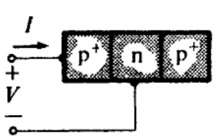
5. The symmetrical p^+–n–p^+ transistor is connected as a diode in the four configurations shown. Assume that $V >> kT/q$. Sketch $\delta p(x_n)$ in the base region for each case. Which connection seems most appropriate for use as a diode? Why?



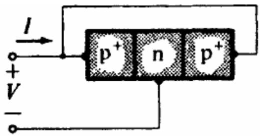
(a)



(b)



(c)



(d)

6. The base doping in a diffused n^+–p–n bipolar transistor can be approximated by an exponential

$$N_B = N_B(0)exp\,(-ax/x_B)$$

where a is a constant and is given by

$$a = \ln\,(N_B(0)/N_B(x_B))$$

(*a*) Show that, in thermal equilibrium, the electric field in the neutral base region is a constant.

(*b*) Indicate the direction of the electric field. Does this electric field aid or retard the flow of minority carrier electrons across the base?

(*c*) Derive an expression for the steady-state minority carrier electron concentration in the base under forward bias. Assume no recombination occurs in the base. (Express the electron concentration in terms of the electron current density.)