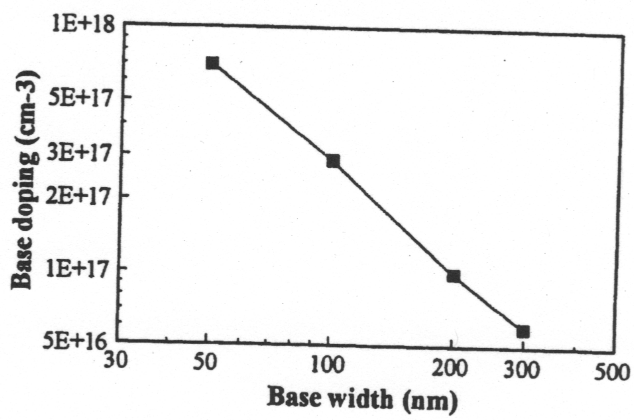
7.2. For a box-like profile, Eq. (7.5) gives

$$R_{Sbi} = \left(q\int_0^{W_B} p_p(x)\mu_p(x)dx\right)^{-1} = \frac{1}{qN_B\mu_p W_B} = \frac{\rho_B}{W_B}, \qquad (1)$$

where ρ_B is the resistivity of the p-type base layer. Setting $R_{Sbi} = 10^4\ \Omega/\square$, and using Fig. 2.8 for ρ_B, we obtain the values in the following table.

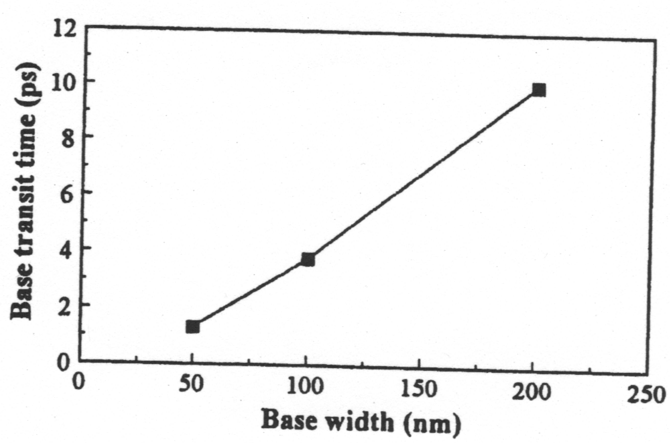
N_B (cm^{-3})	ρ_B (Ω-cm)	W_B (nm)
6×10^{16}	0.3	300
1×10^{17}	0.2	200
2.9×10^{17}	0.1	100
7×10^{17}	0.05	50



7.3. From Exercise 7.2, and Fig. 2.18(a), we have the following table.

W_B (nm)	N_B (cm^{-3})	μ_{nB} (cm^2/V-s)	D_{nB} (cm^2/s)	t_B (ps)
50	7×10^{17}	37.5	9.75	1.3
100	2.9×10^{17}	505	13.1	3.8
200	1×10^{17}	760	19.8	10.1

where we have used $D_{nB} = kT\mu_{nB}/q$ and $t_B = W_B^2/2D_{nB}$. Also, since Fig. 2.18(a) does not have values for $N_B < 1\times10^{17}$ cm^{-3}, we have dropped the corresponding base width and base doping concentration values in the table and the following plot.



7.4. From Eq. (6.72), we have

$$V_A \approx \frac{Q_{pB}}{C_{dBC}} = \frac{qN_B W_B}{C_{dBC}}. \tag{1}$$

To avoid significant base widening, collector current density is kept at

$$J_C = 0.3qv_{sat}N_C, \qquad \text{or} \qquad N_C = \frac{J_C}{0.3qv_{sat}}, \tag{2}$$

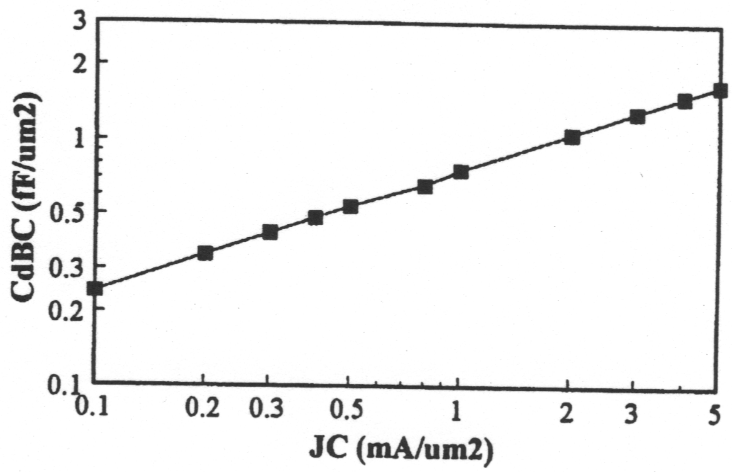
with $v_{sat} = 10^7$ cm/s.

(a) For a one-sided B-C junction, with $V_{CB} = 2$ V, Eqs. (2.68) and (2.70) give

$$C_{dBC} = \frac{\varepsilon_{si}}{W_{dBC}} = \sqrt{\frac{qN_C\varepsilon_{si}}{2(\psi_{bi} + V_{CB})}} = \sqrt{\frac{J_C\varepsilon_{si}}{0.6v_{sat}(\psi_{bi} + V_{CB})}}. \tag{3}$$

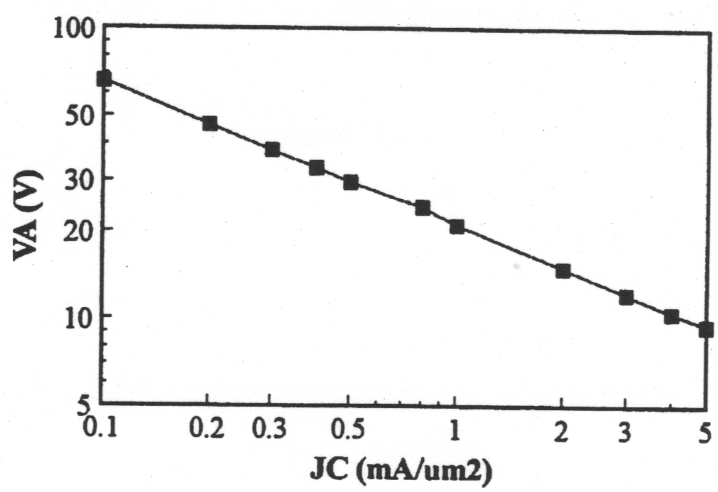
We can obtain ψ_{bi} from Fig. 2.12 (or set it to about 0.95 V as an approximation) and use $\varepsilon_{si} = 1.04\times10^{-12}$ F/cm to generate the following table.

J_C (mA/μm^2)	N_C (cm^{-3})	ψ_{bi} (V)	C_{dBC} (fF/μm^2)
0.1	2.08×10^{16}	0.925	0.243
0.2	4.16	0.945	0.343
0.3	6.24	0.95	0.420
0.4	8.32	0.96	0.484
0.5	1.04×10^{17}	0.97	0.540
0.8	1.66	0.98	0.659
1.0	2.08	0.99	0.761
2.0	4.16	1.0	1.07
3.0	6.24	1.02	1.31
4.0	8.32	1.02	1.52
5.0	1.04×10^{18}	1.02	1.69



(b) For a base design with $qN_BW_B = 1.6\times10^{-6}$ C/cm^2, we have the following table

J_C (mA/μm^2)	C_{dBC} (fF/μm^2)	V_A (V)
0.1	0.243	65.8
0.2	0.343	46.6
0.3	0.420	38.1
0.4	0.484	33.1
0.5	0.540	29.6
0.8	0.659	24.3
1.0	0.761	21.0
2.0	1.07	15.0
3.0	1.31	12.2
4.0	1.52	10.5
5.0	1.69	9.5



7.5. N-P-N transistor with $W_B = 500$ nm and negligible heavy doping effect in base layer, and a graded base profile of

$$N_B(x) = A - \alpha x, \tag{1}$$

$$A = N_B(0) = 2\times10^{17}\ \text{cm}^{-3}, \tag{2}$$

$$N_B(W_B) = 2\times10^{16}\ \text{cm}^{-3} \tag{3}$$

and

$$\alpha = \frac{A - N_B(W_B)}{W_B} = 3.6\times10^{21}\ \text{cm}^{-4}. \tag{4}$$

From Eq. (7.15), the electric field due to the dopant distribution is

$$\mathscr{E}(dopant) = \frac{kT}{q}\frac{1}{N_B(x)}\frac{dN_B}{dx} = -\frac{kT}{q}\frac{\alpha}{N_B(x)}. \tag{5}$$

We have the following table and plot of results.

x (nm)	N_B (cm^{-3})	$\mathscr{E}$ (V/cm)
0	2.0E17	-468
50	1.82E17	-514
100	1.64E17	-571
150	1.46E17	-641
200	1.28E17	-731
250	1.10E17	-851
300	9.2E16	-1017
350	7.4E16	-1265
400	5.6E16	-1671
450	3.8E16	-2463
500	2.0E16	-4680