Summer-2019 UM-SJTU JI Ve311 Homework #3

Instructor: Dr. Chang-Ching Tu

Due: 10:00 am, June 20, 2019 (Thursday) in class

Note:

(1) Please use A4 size papers.

(2) Please use the SPICE model below for simulation.

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.model Qbreakn NPN IS=5e-16 BF=100 VAF=100
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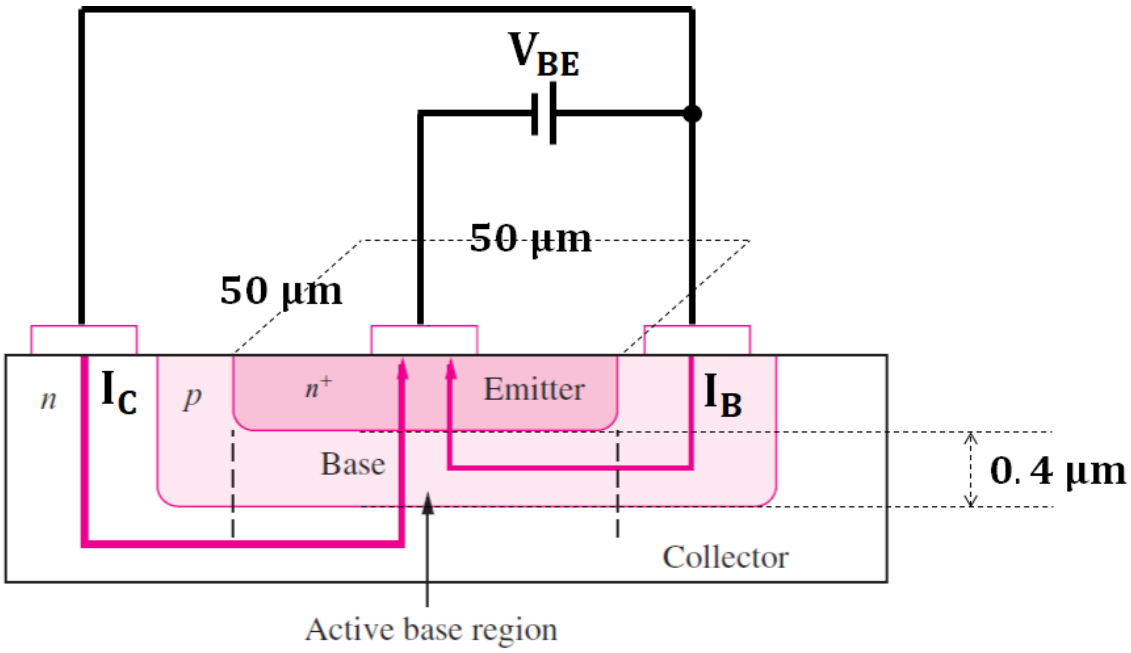
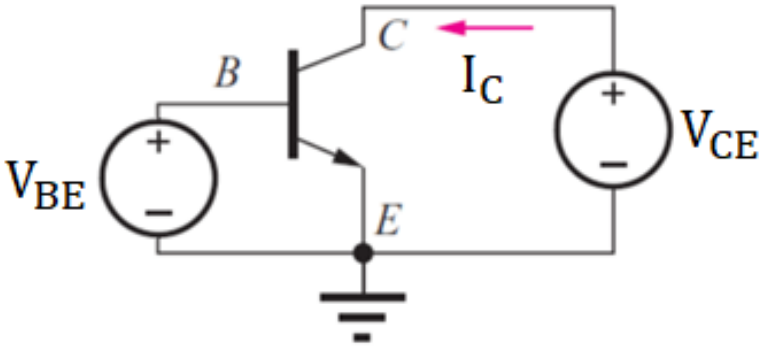
1. [BJT Forward-Active Current] For a npn BJT with cross-section as below:
   (a) [20%] Assuming $V_{BE} = 0.7$ V, calculate the base neutral region width (W_B), and confirm whether $W_B \ll L_n$. (Hint: consider the depletion widths at the base/emitter and base/collector junctions.)
   (b) [30%] Assuming $V_{BE} = 0.7$ V, calculate I_C, I_B and I_E.

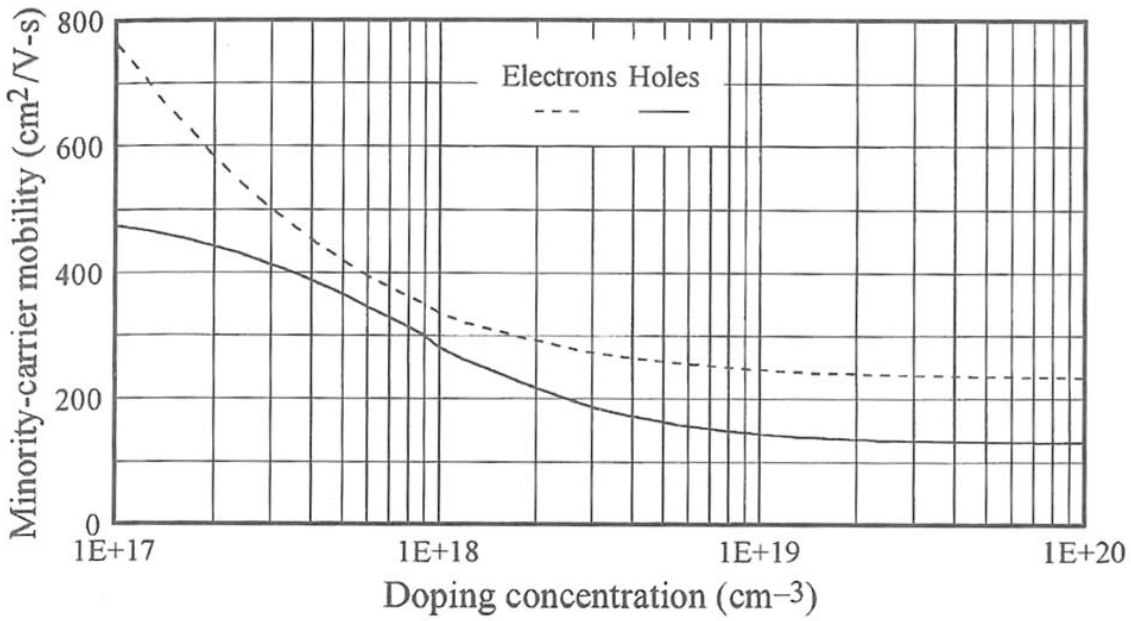
   Note: use the appended graphs for L_n and D_n.

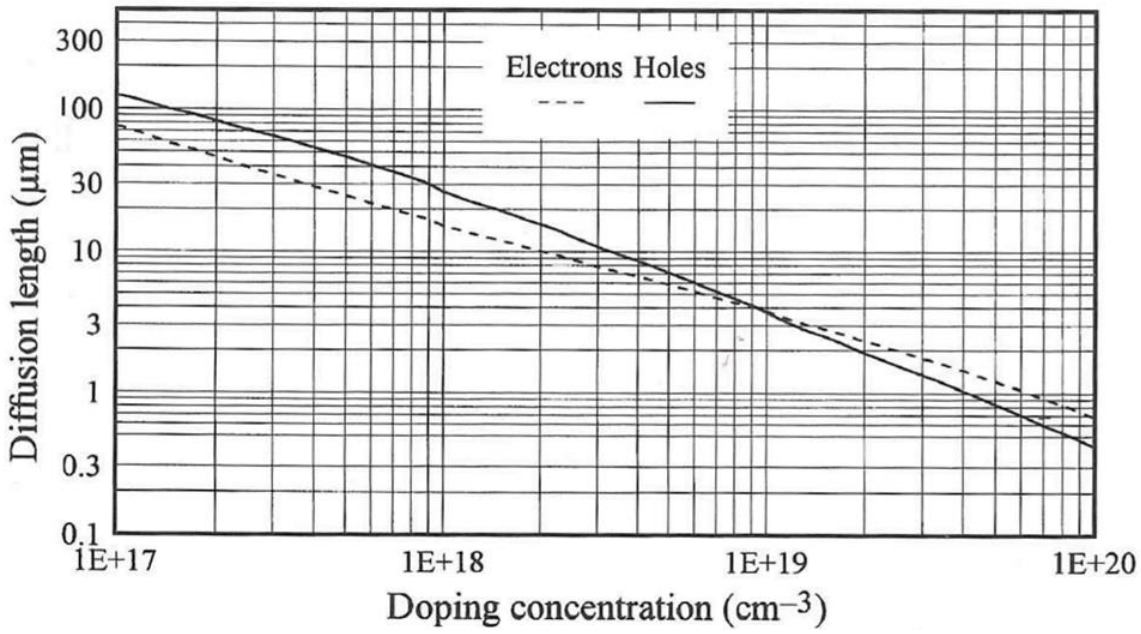


$$N_{d(\text{Emitter})} = 1 \times 10^{20}\ 1/\text{cm}^3$$
$$N_{a(\text{Base})} = 4 \times 10^{17}\ 1/\text{cm}^3$$
$$N_{d(\text{Collector})} = 1 \times 10^{18}\ 1/\text{cm}^3$$

2. [BJT Forward-Active I-V Characteristics] For a npn BJT circuit as below:
   (a) [20%] When $V_{BE} = 0.7\ V$ and $V_{CE} = 2\ V$, use proper equations provided in the course slides and the spice model above to calculate the transconductance gain (gm) and the output impedance (r_o).
   (b) [15%] In Pspice, when $V_{CE} = 2\ V$, plot I_C versus V_{BE} (from 0 to 1 V). Find out the slope at $V_{BE} = 0.7\ V$ and compare it with the gm value calculated in (a).
   (c) [15%] In Pspice, when $V_{BE} = 0.7\ V$, plot I_C versus V_{CE} (from 0 to 5 V). Find out the inverse of slope at $V_{CE} = 2\ V$ and compare it with the r_o value calculated in (a).




Minority-carrier mobility (cm²/V-s)
800
600
400
200
0
Electrons Holes
1E+17
1E+18
1E+19
1E+20
Doping concentration (cm⁻³)


Diffusion length (μm)
300
100
30
10
3
1
0.3
0.1
Electrons Holes
1E+17
1E+18
1E+19
1E+20
Doping concentration (cm⁻³)