UNIVERSITY OF CALIFORNIA, BERKELEY
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE 105: Microelectronic Devices and Circuits   Spring 2008

MIDTERM EXAMINATION #1
Time allotted: 80 minutes

NAME: _____   _____   _____
(print)   Last   First   Signature

STUDENT ID#:   _____

INSTRUCTIONS:
  1. Use the values of physical constants provided below.
  2. SHOW YOUR WORK. (Make your methods clear to the grader!)
  3. Clearly mark (underline or box) your answers.
  4. Specify the units on answers whenever appropriate.

PHYSICAL CONSTANTS				PROPERTIES OF SILICON AT 300K		
Description	Symbol	Value		Description	Symbol	Value
Electronic charge	q	1.6×10^{-19} C		Band gap energy	E_G	1.12 eV
Boltzmann's constant	k	8.62×10^{-5} eV/K		Intrinsic carrier concentration	n_i	10^{10} cm^{-3}
Thermal voltage at 300K	$V_T = kT/q$	0.026 V		Dielectric permittivity	ε_{si}	1.0×10^{-12} F/cm
Note that $V_T \ln(10) = 0.060$ V at T=300K						

Electron and Hole Mobilities in Silicon at 300K
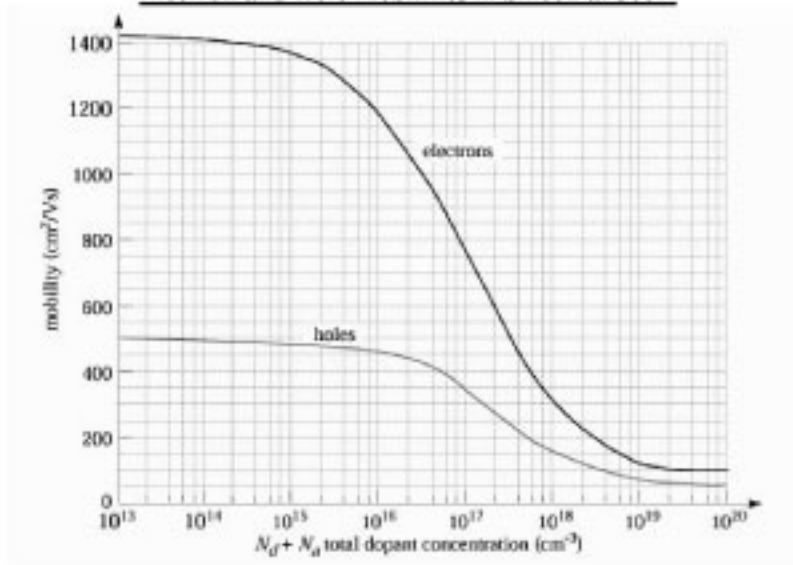
SCORE: 1 _____ / 25

2 _____ / 25

3 _____ / 30

Total: _____ / 80

Problem 1 [25 points]: Semiconductor Basics

a) A Si resistor is doped with 10^{17} cm^{-3} of phosphorus and 2×10^{17} cm^{-3} of boron impurities.

   i) What are the electron and hole concentrations, n and p, in this sample at room temperature? [4 pts]
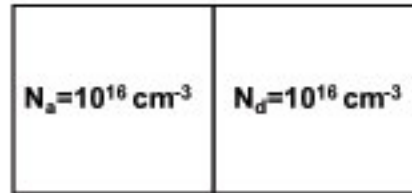
   ii) Estimate the resistivity of this sample. [5 pts]

   We can find μ_p in the mobility chart using $N_A + N_D = 3 \times 10^{17}$ cm^{-3}. Doing so, we find

   iii) Qualitatively (no calculations required), how would the resistivity change when the temperature goes up to 100°C? Explain briefly. [4 pts]

b) Consider the two Si p-n junction diode below:

$N_a=10^{16}$ cm^{-3}	$N_d=10^{18}$ cm^{-3}

$N_a=10^{16}$ cm^{-3}	$N_d=10^{16}$ cm^{-3}
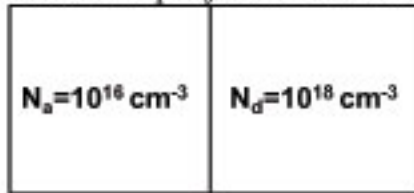
           PN Junction A   **PN Junction B**

**i)** Find the ratio of the built-in voltages for these two p-n junctions. **[4 pts]**

ii) What is the ratio of the current densities under a forward bias voltage of 1V for these two diodes? **[4 pts]**

   Assume $\tau_n = \tau_p = \tau$ (given during exam).

iii) Find the ratio of the areal junction capacitances of these two p-n junctions when they are not biased (i.e., 0V). **[4 pts]**

Problem 2 [25 points]: Bipolar Junction Transistor (BJT)

a)   The following two NPN BJTs have the same doping concentrations. The only difference is their base widths: BJT-A has a base width of 100 nm, while BJT-B has a base width of 200 nm. Find the ratio of their current gains. (If you give correct *qualitative* answer, i.e., which BJT has higher current gain and why, you will get half credit). **[6 pts]**

E   B   C   E   B   C

Emitter: N-type, $N_d = 10^{18}$ cm^{-3}

←→ 100 nm   ←→ 200 nm

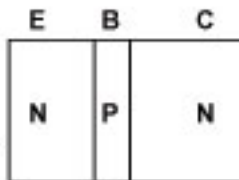Base: P-type, $N_a = 10^{17}$ cm^{-3}

Collector: N-type, $N_d = 10^{16}$ cm^{-3}

BJT-A   BJT-B

b) Consider the following two BJTs. They have identical dimensions and doping profiles, except BJT-A is NPN transistor and BJT-B is PNP transistor. Find the ratio of their current gains. (If you give correct *qualitative* answer, i.e., which BJT has higher current gain and why, you will get half credit). **[6 pts]**
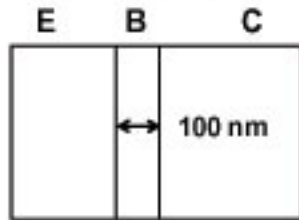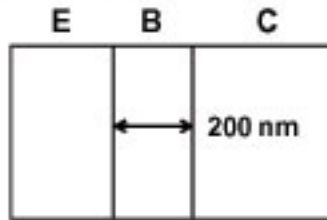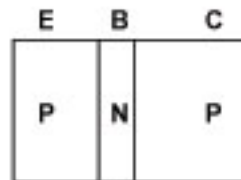
Emitter: N-type, $N_d = 10^{18}$ cm^{-3}

Base: P-type, $N_a = 10^{17}$ cm^{-3}

Collector: N-type, $N_d = 10^{16}$ cm^{-3}

E   B   C   E   B   C

| N | P | N | | P | N | P |

BJT-A   BJT-B

Emitter: P-type, $N_a = 10^{18}$ cm^{-3}
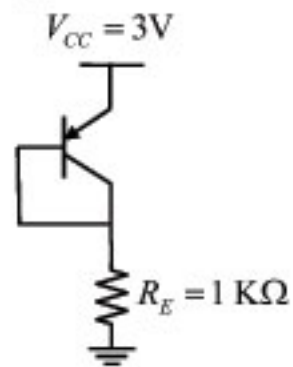
Base: N-type, $N_d = 10^{17}$ cm^{-3}

Collector: P-type, $N_a = 10^{16}$ cm^{-3}

Here, we must again use the assumption that $\tau_n = \tau_p = \tau$.

c) Answer this question *qualitatively*. For the two BJTs in Part a), which BJT will have larger Early voltage? Why? [4 pts]

d) Solve the bias point of the following PNP transistor (I_C, V_{EB}, V_{EC}). Assume $I_S = 10^{17}$ A, β=100, and $V_A = \infty$ [5 pts]
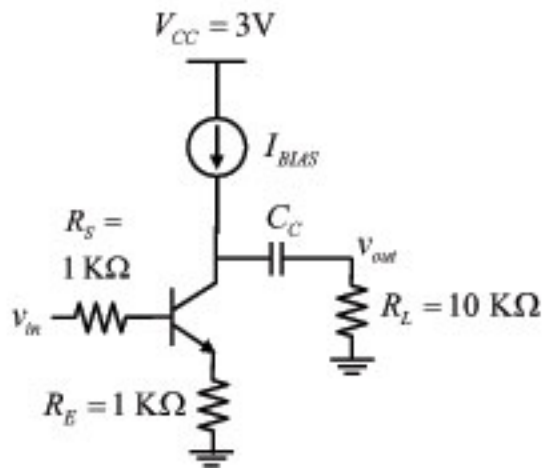
$V_{CC} = 3V$

$R_E = 1$ KΩ

Assume $I_S = 10^{-17}$ A (correction made during exam).

e) Draw the small-signal model of the circuit in Part d). Specify all the small signal parameters used (e.g., g_m, r_π, etc). **[4 pts]**

Problem 3 [30 points]: BJT Amplifiers

a) Consider the BJT amplifier shown below with $I_{BIAS} = 1$ mA.

Assume $I_S = 10^{17}$ A, β=100, and $V_A = 10V$.

i) Find the value of V_{BE}. **[4 pts]**

   Assume $V_C = 2$ V (given during exam) and $I_S = 10^{-17}$ A (correction made during exam).

ii) Is the BJT in the active mode? Why? **[4 pts]**

iii) Find the small signal parameters of the BJT under this bias condition. **[4 pts]**

iv) What is the expression for the voltage gain? What is its numerical value? **[6 pts]**

For this part, assume $V_A = \infty$ (given during exam).

v) What is the expression for the input impedance (seen by v_{in})? What is its numerical value? **[6 pts]**

For this part, assume $V_A = \infty$ (given during exam).

vi) What is the expression for the output impedance (seen by v_{out})? What is its numerical value? **[6 pts]**