**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**

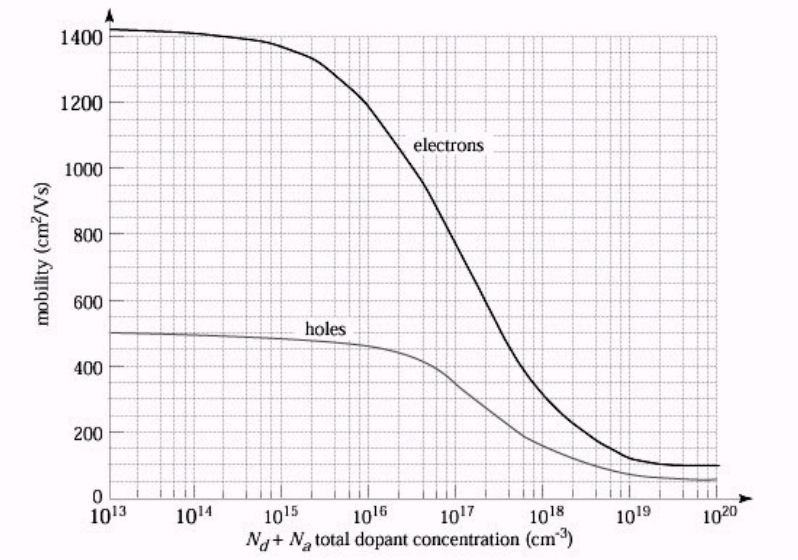
| Description | Symbol | Value |
|---|---|---|
| Electronic charge | $q$ | $1.6\times10^{-19}$ C |
| Boltzmann's constant | $k$ | $8.62\times10^{-5}$ eV/K |
| Thermal voltage at 300K | $V_T = kT/q$ | 0.026 V |

Note that $\boldsymbol{V_T \ln(10) = 0.060}$ **V** at $T$=300K

**PROPERTIES OF SILICON AT 300K**

| Description | Symbol | Value |
|---|---|---|
| Band gap energy | $E_G$ | 1.12 eV |
| Intrinsic carrier concentration | $n_i$ | $10^{10}$ cm$^{-3}$ |
| Dielectric permittivity | $\varepsilon_{Si}$ | $1.0\times10^{-12}$ F/cm |

**Electron and Hole Mobilities in Silicon at 300K**




**SCORE:** **1 _____ / 25**

**2 _____ / 25**

**3 _____ / 30**

**Total:** **_____ / 80**

**Problem 1 [25 points]: Semiconductor Basics**

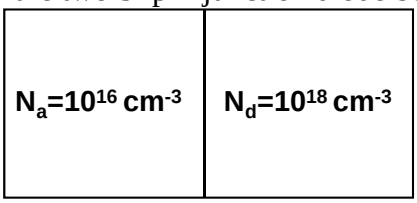
**a)** A Si resistor is doped with $10^{17}$ $cm^{-3}$ of phosphorus and $2x10^{17}$ $cm^{-3}$ of boron impurities.

**i)** What are the electron and hole concentrations, *n* and *p*, in this sample at room temperature? **[4 pts]**

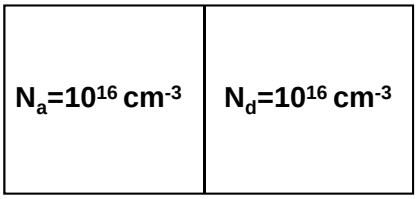
**ii)** Estimate the resistivity of this sample. **[5 pts]**

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

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




**PN Junction A**




**PN Junction B**

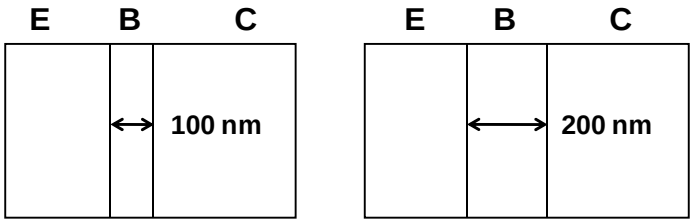
**i)** Find the ratio of the built-in voltages for these two p-n junctions. **[4 pts]**

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

**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]**




BJT-A BJT-B

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

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

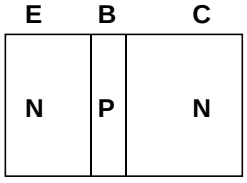
Collector: N-type, $N_d = 10^{16}$ cm$^{-3}$

**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]**

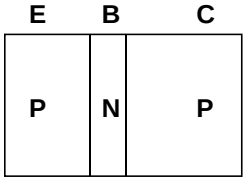
Emitter: N-type, $N_d = 10^{18}$ cm$^{-3}$

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

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




BJT-A




BJT-B

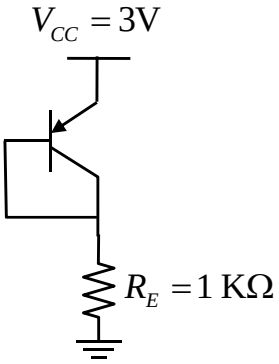
Emitter: P-type, $N_a = 10^{18}$ cm$^{-3}$

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

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

**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, $\beta$=100, and $V_A = \infty$ **[5 pts]**

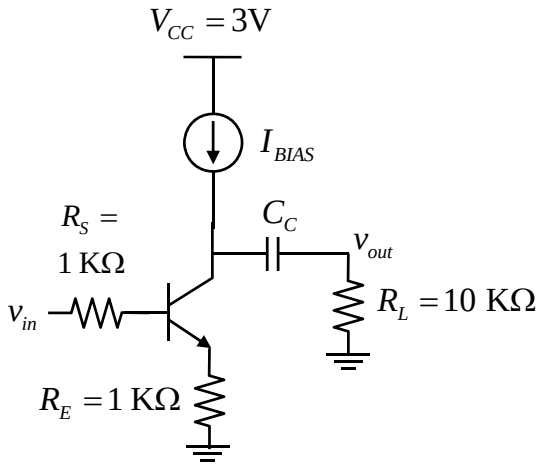


**e)** Draw the small-signal model of the circuit in Part d). Specify all the small signal parameters used (e.g., $g_m$, $r_\pi$, etc). **[4 pts]**

**Problem 3 [30 points]: BJT Amplifiers**

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

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




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

**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]**

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

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