Name: KEY **Id#**

COE 360, Term 071

Principles of VLSI Design
Quiz# 1

Date: Wednesday, Sep. 29, 2004

Q1. Fill in the blank:

(1) **Drift current** is the motion of charges due to the application of an electric field.

(2) **Diffusion current** is the motion of charges resulting from a non-uniform charge distribution.

(3) The current per unit area in a conducting medium is called the **current density**.

(4) **Mobility** describes the ease with which charge carriers drift in the material.

(5) Drift velocity **decreases** with the increase of the area of a conducting medium.

(6) Drift velocity **decreases** with the increase of the charge carriers concentration per unit volume.

(7) The conductivity of a material increases with the increase in the **charge carriers concentration per unit volume** and **mobility**.

(8) The electric field across a conductor increases with the increase in **voltage** and decrease in **length**.

(9) The resistance of a conductor increases with the increase in **length** and the decrease in **conductivity** and **area.**

(10) A silicon atom has **14** electrons, **4** of which are valence electrons.

(11) At T=0°K, all the valence electrons in a silicon semiconductor are in the **valence** band.

(12) **Intrinsic** semiconductors are pure crystals that contain no foreign atoms or impurities

(13) **Fermi** energy is the energy level below which all the energy states are filled with electrons and above which all the states are empty at T=0°K.

(14) In an intrinsic semiconductor, at a given temperature, the concentration of free electrons is **equivalent to** the concentration of free holes.

(15) The addition of trivalent atoms to an intrinsic semiconductor results in a **p-**type material, while the addition of pentavalent atoms to an intrinsic semiconductor results in a **n-**type.

(16) The majority charge carriers in an n-type material are **electrons** while the minority charge carriers are **holes**.

(17) The mass action law states that under thermal equilibrium, the concentration of free electrons times the concentration of free holes is constant and is equal to $\mathbf{n_i^2}$.

(18) If an intrinsic semiconductor material is doped with acceptor impurities, the number of free holes **increases** while the number of free electrons **decreases**.

(19) The charge neutrality law states that under thermal equilibrium, the semiconductor crystal is electrically **neutral**.

(20) The concentration of free electrons in an n-type material doped with donor concentration N_d is nearly $\mathbf{N_d}$ and the concentration of free holes is $\mathbf{n_i^2 / N_d}$.

(21) The conductivity of a semiconductor material **increases** with increasing temperature.

(22) The Fermi level for an n-type semiconductor is **above** the intrinsic Fermi level E_{Fi} while the Fermi level for a p-type semiconductor is **below** E_{Fi} .

(23) As the doping level increases, the Fermi energy level moves closer to the valence band for the **p-type** material and closer to the conduction band for the **n-type** material.

(24) Further diffusion across a PN junction is stopped by the **electric field** produced by **the positive and negative charges in the depletion region**.

(25) Increasing the doping concentration **increases** the built-in potential across the PN junction.

(26) The width of the depletion region **decreases** with increasing the doping concentration.

(27) In a reverse biased PN junction, the junction potential **increases** and the depletion region width **increases**.

(28) If a positive voltage is applied to the p-region with respect to the n-region, the PN junction is called **forward-biased**.

(29) Transition capacitance across the PN junction **increases** with increasing the doping concentration.

(30) The higher the doping concentrations of the PN junction are the **lower** the breakdown voltage.

Q2. Determine the **electron and hole concentrations** and the **conductivity** of a piece of silicon at 300°K given that it is doped with Arsenic (pentavalent) at a density of $4X10^{16}$ atoms/cm^3 and doped with Boron (trivalent) at a density of $4X10^{12}$ atoms/cm^3. *Assume the following: Electron mobility at 300°K=1500* $cm^2/V.s$*, Hole mobility at 300°K = 475* $cm^2/V.s$*, Intrinsic concentration at 300°K=*$1.45X10^{10}$ cm^{-3}, q= $1.6X10^{-19}$*. Indicate clearly the* ***units*** *in your solution.*

Since $N_d >> N_a$ and $N_d >> n_i$, the material will be n-type material.
Thus, $n \approx N_d = 4X10^{16}$ cm^{-3}.
$P \approx n_i^2 / N_d = (1.45X10^{10})^2 / 4X10^{16} = 5.26X10^3$ cm^{-3}.

$\sigma \approx q\ n\ \mu_n = 1.6X10^{-19}\ X\ 4X10^{16}\ X\ 1500 = 9.6\ (\Omega\ cm)^{-1}$.