## Reading assignment:

## Chapters 3 and 4 of the textbook

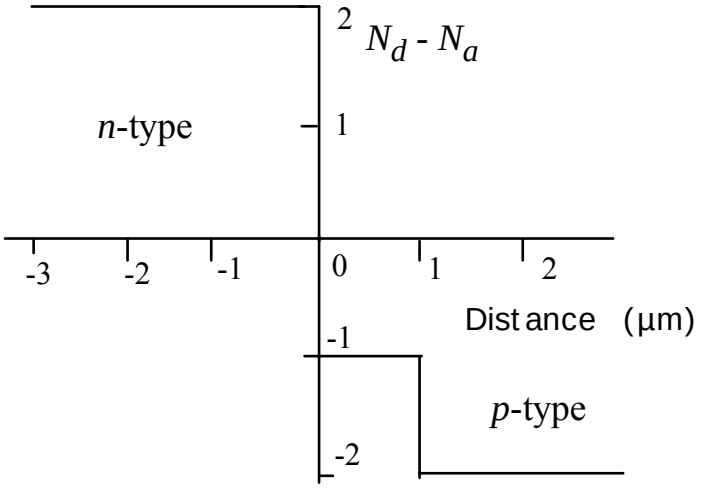
## SDM-1 Michael Shur
## Homework # 3

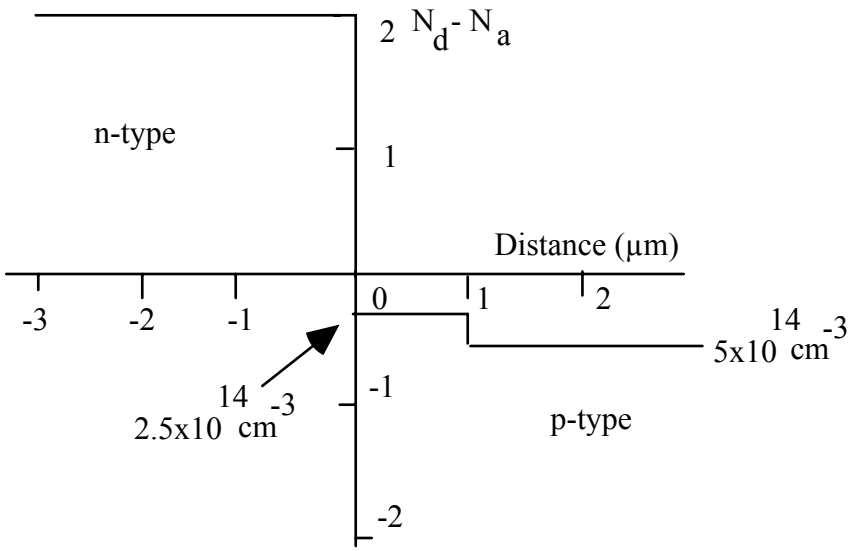
## 1: 20 points/ 2: 20 points. 3: 20 points/ 4: 20 points 5: 20 points

1. Given the built-in voltage, $V_{bi}$, for a $p^+$-$n$ junction, derive the equation relating the ratio of the depletion width of the $p^+$-$n$ junction (at zero bias) over the Debye radius at a given temperature, $T$. Assume zero bias voltage.

2. Calculate and plot electron and hole concentrations versus distance for a $p^+$-$n$ silicon junction with the acceptor density in the $p$-type region, $N_a = 10^{16}$ cm$^{-3}$ and with the donor density in the $n$-type region, $N_d = 10^{14}$ cm$^{-3}$ at room temperature and zero bias voltage. The dielectric permittivity of Si is 1.05x10$^{-10}$ F/m. The energy gap of Si is 1.12 eV. The densities of states in the conduction and valence bands at room temperature are 3.22x10$^{19}$ cm$^{-3}$ and 1.83x10$^{19}$ cm$^{-3}$, respectively.

3. Sketch the field distributions in a $p$-$n$ silicon junction with doping profiles shown in the figures. Assume zero applied bias and room temperature ($n_i \approx 10^{10}$ cm$^{-3}$). The silicon dielectric permittivity is 1.05x10$^{-10}$ F/m.



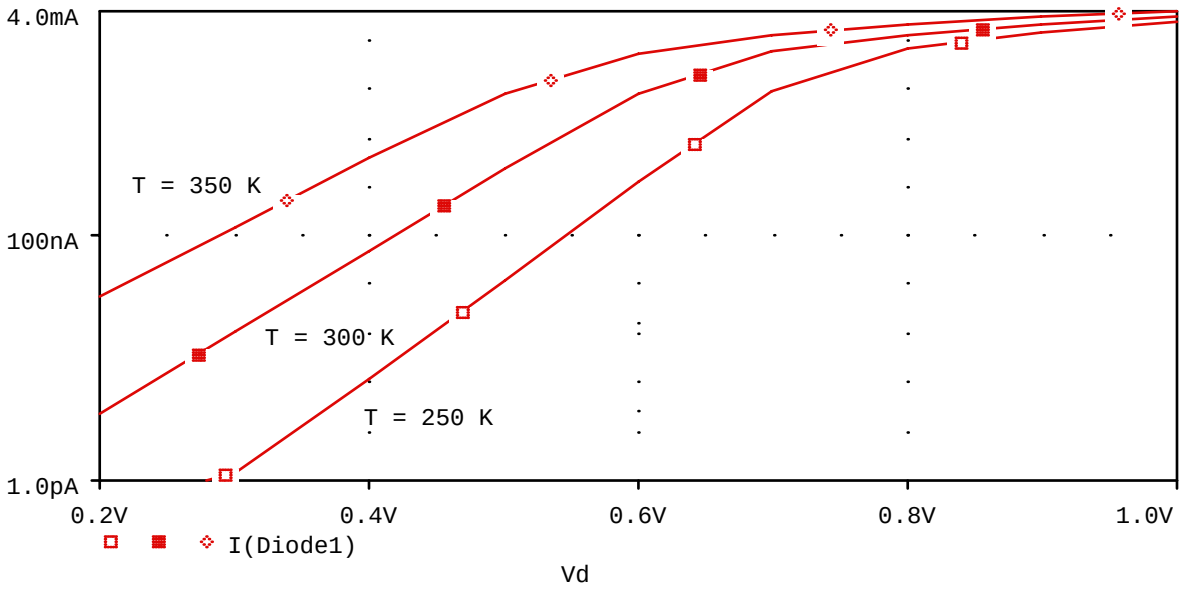



Vertical axis - doping in $10^{15}$ $cm^{-3}$. Positive values correspond to *n*-type, negative to *p*-type.

4. From the *I-V* characteristics of the *p-n* junction shown in the figure, estimate the diode saturation current, the ideality factor, and series resistance. Using the following empirical equation for the temperature dependence of the saturation current, estimate the energy gap of the semiconductor material of the diode:

$$I_s(T) = I_s(T_o)\left(\frac{T}{T_o}\right)^{\frac{\kappa}{\eta}} \exp\left(\frac{E_g}{k_B T_o}\right) \exp\left(-\frac{E_g}{k_B T}\right)$$

(Assume that $\kappa/\eta = 0$.)

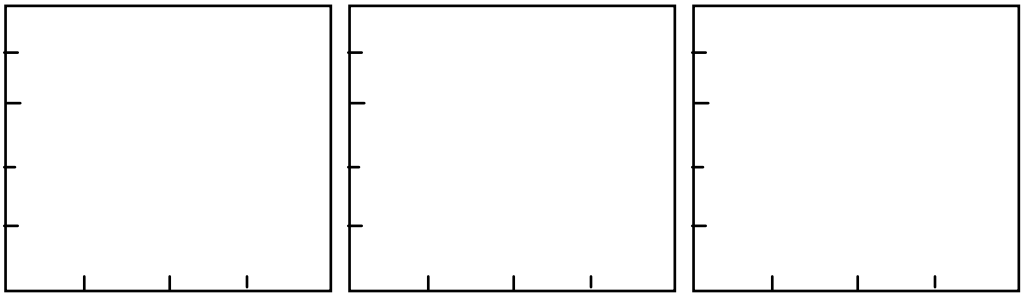


**5. /20**

. Consider a Si *p*-*n* junction with doping of $10^{15}$ $cm^{-3}$ in both the *p*-type region and *n*-type regions. The intrinsic carrier concentration is $10^{10}$ $cm^{-3}$. Temperature, $T$ = 300 K. Silicon dielectric permittivity is $1.05 \times 10^{-10}$ F/m.

Sketch a band diagram for

a. zero bias
b. 0.3 forward bias
c. 1 volt reverse bias
Show the scales.



Zero bias Forward bias 0.3 V Reverse bias 1 V