NAME UCID

General

$$
\begin{aligned}
n &= \frac{N_D - N_A}{2} + \sqrt{\left(\frac{N_D - N_A}{2}\right)^2 + n_i^2} \\
&= N_D - N_A \text{ if } N_D - N_A > 10n_i \\
p &= \frac{N_A - N_D}{2} + \sqrt{\left(\frac{N_A - N_D}{2}\right)^2 + n_i^2} \\
&= N_A - N_D \text{ if } N_A - N_D > 10n_i \\
np &= n_i^2 \text{ at equilrium} \\
n &= n_0 + n' \\
p &= p_0 + p' \\
n &= N_C e^{-(E_C - E_F)/kT} \\
p &= N_V e^{-(E_F - E_V)/kT} \\
D &= (kT/q)\mu \\
dE/dx = \rho/\epsilon &\;;\; |E| = \nabla V
\end{aligned}
$$

Junction

$$
\begin{aligned}
V_{bi} &= (kT/q)\ln(N_A N_D/n_i^2) \\
W_{dep} &= \sqrt{\frac{2\epsilon(V_{bi} - v)}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)} \\
x_N N_D &= x_P N_A \\
C &= \epsilon A/d \\
n'(x_P) &= n(x_P) - n_{P0} = n_{P0}\left(e^{v/v_T} - 1\right) \\
p'(x_N) &= p(x_N) - p_{N0} = p_{N0}\left(e^{v/v_T} - 1\right) \\
n'(x) &= n'(x_P)\left(e^{-(x - x_P)/{}_nL_p}\right) \text{ for } x > x_P \\
p'(x) &= p'(x_N)\left(e^{-(x - x_N)/{}_pL_n}\right) \text{ for } x > x_N \\
{}_nL_p = \sqrt{{}_n\tau_p D_n} &\;;\; {}_pL_n = \sqrt{{}_p\tau_n D_p}
\end{aligned}
$$

$$
\begin{aligned}
J_{\text{n,df,p region}}(x) &= (qD_n/{}_nL_p)n'(x) \\
J_{\text{p,df,n region}}(x) &= (qD_p/{}_pL_n)p'(x)
\end{aligned}
$$

Universal constants

$$
\begin{aligned}
k &= 1.38 \times 10^{-23}\ J/K \\
h &= 6.63 \times 10^{-34}\ Js \\
q &= 1.60 \times 10^{-19}\ C \\
m_0 &= 9.1 \times 10^{-32}\ kg \\
\epsilon_o &= 8.85 \times 10^{-12}\ F/m
\end{aligned}
$$

@300K

$$
\begin{aligned}
kT &= 26\ meV \\
v_T = kT/q &= 26\ mV
\end{aligned}
$$

Silicon@300K

$$
\begin{aligned}
N_C &= 2.8 \times 10^{19}/cm^3 \\
N_V &= 1.0 \times 10^{19}/cm^3 \\
n_i &= 1.0 \times 10^{10}/cm^3 \\
E_g &= 1.1\ eV \\
\epsilon_r &= 12 \\
\mu_n &= 1400\ cm^2/Vs \\
\mu_p &= 470\ cm^2/Vs
\end{aligned}
$$

Germanium@300K

$$
\begin{aligned}
N_C &= 1.0 \times 10^{19}/cm^3 \\
N_V &= 6.0 \times 10^{18}/cm^3 \\
n_i &= 2.0 \times 10^{13}/cm^3 \\
E_g &= 0.67\ eV \\
\epsilon_r &= 16 \\
\mu_n &= 3900\ cm^2/Vs \\
\mu_p &= 1900\ cm^2/Vs
\end{aligned}
$$

1. *(2 marks)* Complete the table below for a an n^+p junction

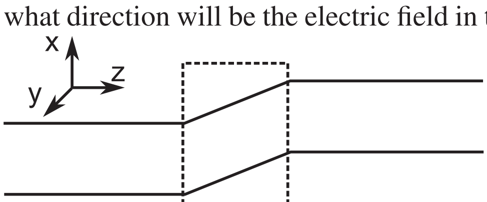
	Always	Never	It depends
The depletion region is mostly on the n side	○	○	○
The p side of the depletion regions stores more charge than the n side	○	○	○
Under reverse bias, the depletion capacitance increases	○	○	○
Under forward bias, the charge stored in the n side of the depletion region increases	○	○	○

2. *(2 marks)* Answer true or false. For a forward biased pn junction

(a) Electrons on the n side predominanatly flow by diffusion

(b) Excess hole concentration on the p side decreases exponentially with distance from the p depletion edge

3. *(2 marks)* Consider the band diagram of a pn junction at equilibrium below. Given the co-ordinate system, in what direction will be the electric field in the region enclosed in the dashed box. Justify your answer for any credit.



4. Consider a **silicon** junction at x=0. At zero bias, the magnitude of the electric field near the junction was found to be $E_0(10^{-6} - 2|x|)$ where x is in meters, $|.|$ denotes the absolute value and E_0=1.25×10^{12} V/m.

(a) Find the width of the depletion region

(b) Find the built-in potential of the junction

(c) Find the minority concentration on the n depletion edge at equilibrium and at a 390 mV forward bias.

(d) If, under the bias of part (c), the electron concentration on the n side 5 μm from the depletion edge is 99.99% of the maximum electron concentration on that side, find the hole lifetime on the n side