Prob. 5.13

(a) Why is C_s negligible in reverse bias?

For reverse bias of more than a few tenths of a volt, $\Delta p_n \approx -p_n$. Changes in the reverse bias do not appreciably alter the (negative) excess hole distribution. The primary variation is in the width of the depletion region, giving rise to the junction capacitance.

(b) With equal doping, which carrier dominates injection in a GaAs junction?

Electron injection dominates since $\mu_n \gg \mu_p$. With $n_n = p_p$ it is clear that a carrier with higher mobility will determine the injection.

Prob. 5.15

Show $\mathcal{E}_o$ depends on doping of a lightly doped substrate.

$$\mathcal{E}_o = -\frac{q}{\epsilon}\cdot N_d \cdot x_{n_o} = -\left[\frac{2\cdot q\cdot V_o}{\epsilon}\cdot\left(\frac{N_a\cdot N_d}{N_a+N_d}\right)\right]^{\frac{1}{2}} = -\left[\frac{2\cdot q\cdot V_o}{\epsilon}\cdot\left(\frac{1}{N_a}+\frac{1}{N_d}\right)^{-1}\right]^{\frac{1}{2}}$$

the lightly doped side dominates so the doping variation of V_o has only a minor effect

$$\mathcal{E}_o = -\frac{q}{\epsilon}\cdot N_d \cdot x_{n_o} = -\left[\frac{2\cdot q\cdot V_o\cdot N_d}{\epsilon}\right]^{\frac{1}{2}}$$

Prob. 5.20

Find the total forward bias junction capacitance and reverse bias electric field.

For n^+ - p in reverse bias,

$$C_j = \frac{A \cdot \epsilon_s}{W} = \frac{A}{2} \cdot \sqrt{\frac{2 \cdot q \cdot \epsilon_s}{V_o - V} \cdot N_a} = \frac{25\mu m^2}{2} \cdot \sqrt{\frac{2 \cdot 1.6 \cdot 10^{-19} C \cdot 11.8 \cdot 8.85 \cdot 10^{-14} \frac{F}{cm}}{0.026V \cdot \ln\left(\frac{10^{16} \frac{1}{cm^3} \cdot 10^{20} \frac{1}{cm^3}}{\left(1.5 \cdot 10^{10} \frac{1}{cm^3}\right)^2}\right) - (-2V)} \cdot 10^{16} \frac{1}{cm^3}} = 4.2 \cdot 10^{-15} F$$

For n^+ - p in forward bias,

$$J = J_o \cdot \left(e^{\frac{qV}{kT}} - 1\right) = 10^{-9} \frac{A}{cm^2} \cdot \left(e^{\frac{0.5V}{0.026}} - 1\right) = 0.225 \frac{A}{cm^2}$$ because only drift current

$J = q \cdot \mu_p \cdot N_a \cdot \mathcal{E}$ in p region far from junction

$$\mathcal{E} = \frac{0.225 \frac{A}{cm^2}}{1.6 \cdot 10^{-19} C \cdot 250 \frac{cm^2}{V \cdot s} \cdot 10^{16} \frac{1}{cm^3}} = 0.56 \frac{V}{cm}$$

Prob. 5.21

In a p^+- n junction with n-doping changed from N_d to $2N_d$, describe the changes in junction capacitance, built-in potential, breakdown voltage, and ohmic losses.

a) junction capacitance increases
b) built-in potential increases
c) breakdown voltage decreases
d) ohmic losses decrease

Prob. 5.24

Find the new junction capacitance for the given changes.

$$C_j \propto \left(\frac{N_d}{V_r}\right)^{\frac{1}{2}} \qquad C_{j,original} = 10pF$$

$$C_{j,new} \propto \left(\frac{2 \cdot N_d}{8 \cdot V_r}\right)^{\frac{1}{2}} = \tfrac{1}{2} \cdot \left(\frac{N_d}{V_r}\right)^{\frac{1}{2}} \qquad C_{j,new} = \tfrac{1}{2} \cdot C_{j,original} = 5pF$$