5

5.17

A Si p^+-n junction has a donor doping of $5 \times 10^{16}\ cm^{-3}$ on the n side and a cross-sectional area of $10^{-3}\ cm^2$. If $\tau_p = 1\ \mu s$ and $D_p = 10\ cm^2/s$, calculate the current with a forward bias of $0.5\ V$ at $300\ K$.

✓ Answer ⌄

$p_n = \frac{n_i^2}{N_d}$
$L_p = \sqrt{\tau_p D_p}$
$I_p = qA\frac{D_p}{L_p}p_n(e^{qV/kT} - 1)$
$I_p = qA\frac{D_p}{\sqrt{\tau_p D_p}}\frac{n_i^2}{N_d}(e^{qV/kT} - 1)$
$I_p = qA\frac{D_p}{\sqrt{\tau_p D_p}}\frac{n_i^2}{N_d}(e^{qV/kT} - 1)$
$I \approx I_p = 5.513 \times 10^{-7}\ A$

5.19

a

A Si p^+-n junction $10^{-2}\ cm^2$ in area has $N_d = 10^{15}\ cm^{-3}$ doping on the n side. Calculate the junction capacitance with a reverse bias of $10\ V$.

✓ Answer

$C_j = \frac{\epsilon_r \epsilon_0 A}{W}$
$W = \sqrt{\frac{2\epsilon(V_0 - V)}{q}\left(\frac{N_a + N_d}{N_a N_d}\right)} \approx \sqrt{\frac{2\epsilon V_r}{q}\left(\frac{1}{N_d}\right)}$
$C_j = A\sqrt{\frac{q\epsilon_r\epsilon_0 N_d}{2V_r}}$
$C_j = 2.890 \times 10^{-11}\ F$

b

An abrupt p^+-n junction is formed in Si with a donor doping of $N_d = 10^{15}\ cm^{-3}$. What is the depletion region thickness W just prior to avalanche breakdown?

✓ Answer

I could not find the formula for anything related to avalanche breakdown on the slides or in the text, but the W region should increase in size, but with a strong enough field that a multiplicative effect is realized in electrons with EHPs.

5.24

A Si p-n junction with cross-sectional area $A = 0.001\ cm^2$ is formed with $N_a = 10^{15}\ cm^{-3}$ and $N_d = 10^{20}\ cm^{-3}$.

Calculate:

a

Contact potential V_0.

✓ **Answer**

$V_0 = \frac{kT}{q} \ln\left(\frac{N_a N_d}{n_i^2}\right)$

$V_0 = 0.8735512160281839\ V$

b

Space-charge width at equilibrium (zero bias).

✓ **Answer**

$W = \sqrt{\frac{2\epsilon(V_0 - V)}{q}\left(\frac{N_a + N_d}{N_a N_d}\right)}$

$W = 1.067859223747202\ \mu m$

c

Current with a forward bias of $0.7\ V$. Assume $\mu_n = 1500\ cm^2/Vs$, $\mu_p = 450\ cm^2/Vs$, and $\tau_n = \tau_p = 2.5\ ms$. Which carries most of the current, electrons or holes, and why? If you wanted to double the electron current, what should you do?

✓ **Answer**

$I_p = qA\frac{D_p}{L_p}p_n(e^{qV/kT} - 1)$

$I_n = qA\frac{D_n}{L_n}n_p(e^{qV/kT} - 1)$

$L = \sqrt{D\tau}$

$\frac{kT}{q} = \frac{D}{\mu}$

$p_n = \frac{n_i^2}{N_d}$

$n_p = \frac{n_i^2}{N_a}$

$I_p = qA\sqrt{\frac{kT\mu_p}{q\tau_p}}\frac{n_i^2}{N_d}(e^{qV/kT}-1)$
$I_n = qA\sqrt{\frac{kT\mu_n}{q\tau_n}}\frac{n_i^2}{N_a}(e^{qV/kT}-1)$

$I_p = 1.344 \times 10^{-8}\ A$
$I_n = 0.002453\ A$

$I_p > I_n$ therefore the holes carry more current.

$I = I_n = 2.453\ mA$

I would decrease N_d

5.45

A shottky barrier is formed between a metal having a work function of $4.3\ eV$ and p-type Si (electron affinity = $4\ eV$). The acceptor doping in the Si is $10^{17}\ cm^{-3}$.

a

Draw the equilibrium band diagram, showing a numerical value for qV_0.

✓ **Answer**

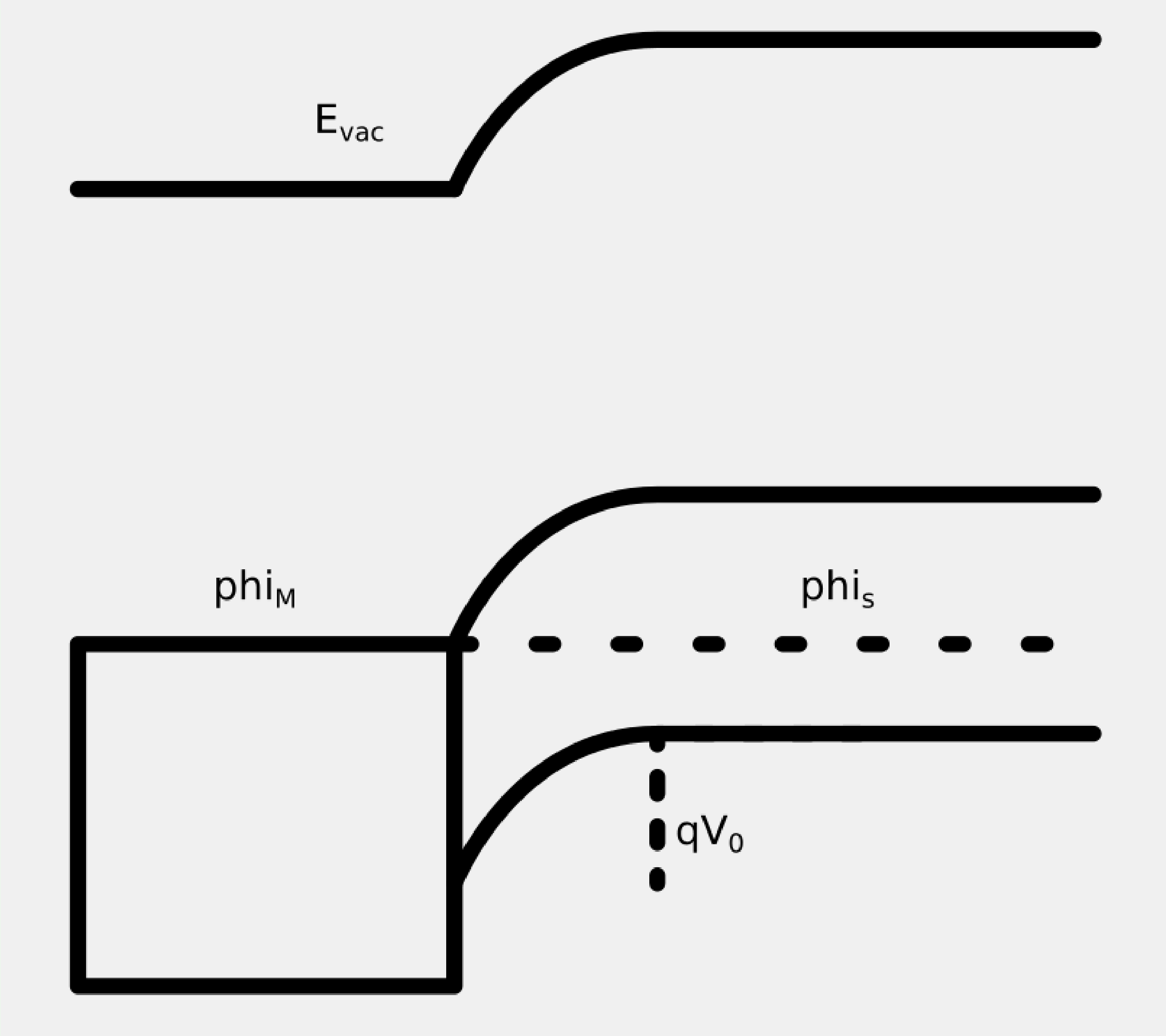
$\phi_M = 4.3\ eV$
$\chi_{si} = 4\ eV$
$N_a = 10^{17}\ cm^{-3}$

$p_0 = n_i e^{(E_i - E_F)/kT}$
$E_i - E_F = kT\ln\left(\frac{p_0}{n_i}\right)$
$E_i - E_F = 0.406957131059819\ eV$

$\phi_s = E_g + \chi_{si} + E_F - E_V = 4.71\ eV$

$\phi_s > \phi_M$

$V_0 = \phi_s - \phi_M = 0.41\ eV$



b

Draw the band diagram with $0.3\ V$ forward bias. Repeat for $2\ V$ reverse bias.

✓ **Answer**

The barrier height would change depending on the bias

With a $0.3\ V$ forward, we would have $qV_0 = 0.11\ eV$
With a $2\ V$ reverse, we would have $qV_0 = 2.41\ eV$