4.9

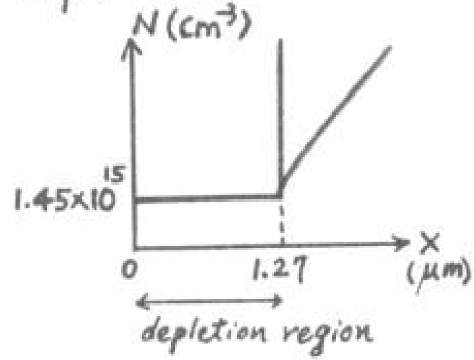
(a) $\dfrac{\Delta(1/C_d^2)}{\Delta(\phi_i - V_a)} = 8.33 \times 10^{25} F^{-2} V^{-1}$

For a one-sided step junction

$C_d = A\left(\dfrac{q\epsilon_s N}{2}\right)^{1/2}(\phi_i - V_a)^{-\frac{1}{2}}$, $N = \dfrac{2C_d^2(\phi_i - V_a)}{A^2 q\epsilon_s} = \dfrac{2}{A^2 q\epsilon_s}\left(\dfrac{1/C_d^2}{\phi_i - V_a}\right)^{-1} = 1.45 \times 10^{15}\ cm^{-3}$

(b) $x_d = \dfrac{\epsilon_s A}{C_d}$, $C_{d\,min} = (1.5 \times 10^{26})^{-\frac{1}{2}} = 81.6\ fF$

$\therefore x_{d\,max.} = 1.27\,\mu m$



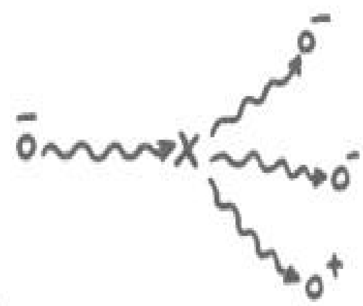
(c) $\phi_i = \dfrac{kT}{q}\ln\dfrac{N_a N_d}{n_i^2} = 0.8V$

$N' = \dfrac{n_i^2}{N}e^{q\phi_i/kT} = 3.34 \times 10^{18}$

$N'/N = 2300$, so the assumption of one-sided step junction is good.

4.11

	energy	momentum
Before collision	$E_0 = \frac{1}{2}mv_0^2$	mv_0
After collision each particle has	(Kinetic energy) $E_f = \frac{1}{2}mv_f^2$	mv_f



By conservation of energy

E_0 = potential energy change + kinetic energy $= E_g + 3E_f$

By conservation of momentum $mv_0 = 3mv_f$ so $v_f = \frac{1}{3}v_0$

$\therefore \frac{1}{2}mv_0^2 = E_g + \frac{3}{2}mv_f^2 = E_g + \frac{3}{2}m\left(\frac{v_0^2}{9}\right)$ $\quad\therefore mv_0^2 = 3E_g$ and

$E_0 = \frac{1}{2}mv_0^2 = \frac{3}{2}E_g$.

Problem 7.5

Note: Changes need to be made to this problem to get meaningful numbers: The horizontal intercept should be changed to 0.78 V and the area of the junction should be 10^{-3} cm^{-3}.

(a) Refer to the discussion on page 138 from which we see that the built-in potential is the intercept on the horizontal axis of the graph in Figure P7.5. Thus

$$\phi_b = 0.78\text{V} \quad \text{(if the suggested change is made)}$$

$$\text{(0.73 V as drawn)}$$

(b) From Equation 7.96 we find that the slope of the curve is

$$\text{Slope} = \frac{-2}{\varepsilon q N_{Dn} A^2}$$

so we have

$$N_{Dn} = \frac{-2}{\varepsilon q A^2(\text{slope})} = \frac{2}{10^{-12} \times 1.6 \times 10^{-19} \times 10^{-6} \times 0.5 \times 10^{22}} = 2.5 \times 10^{15}\ \text{cm}^{-3}$$

(c) Using Equation 7.13 we find

$$N_{Ap} = \frac{10^{20}}{2.5\text{x}10^{15}}\ e^{0.78/0.026} \approx 4 \times 10^{17}\ \text{cm}^{-3}$$

One could also have used the 60 mV rule to find that a built-in potential of 0.78V implies that $N_{Ap}N_{Dn}/N_i^2 = 10^{13}$ since 0.78 divided by 0.06 is 13.

(d) The doping level change is evidence by the change in the slope of the $1/C^2$ curve. This occurs when $1/C^2 = 2 \times 10^{22}\ f^{-2}$.

(i) $C = \varepsilon A/xd$ so

$$x_d = \frac{\varepsilon A}{C} = \varepsilon A\sqrt{1/C^2} = 10^{-12} \times 10^{-3} \times 1.4 \times 10^{11} = 1.4 \times 10^{-4}\ \text{cm} = 1.4\ \mu\text{m}$$

(ii) The slope increases by a factor of 2 so the doping decreases by a factor of 2 to 1.25×10^{15} cm^{-3}.

(e) The slope would decrease to almost zero when C is $\varepsilon A/x$, with x equal to 3 μm. This occurs when

$$\frac{1}{C^2} = \frac{x^2}{\varepsilon^2 A^2} = \frac{9 \times 10^{-8}}{10^{-24} \times 10^{-6}} = 9 \times 10^{22}\ f^{-2}$$