Thus, in 1D, utilizing the Einstein relationship, the electric field can be written as

$$\vec{E} = \frac{kT}{q}\frac{1}{p_o}\frac{\mathrm{d}p_o}{\mathrm{d}x} \tag{3.92}$$

Rewriting equation (3.85) and substituting equation (3.92) yields

$$V_{\mathrm{bi}} = \int_{-x_N}^{x_P} \vec{E}\mathrm{d}x = \int_{-x_N}^{x_P} \frac{kT}{q}\frac{1}{p_o}\frac{\mathrm{d}p_o}{\mathrm{d}x}\mathrm{d}x = \frac{kT}{q}\int_{p_o(-x_N)}^{p_o(x_P)} \frac{\mathrm{d}p_o}{p_o} = \frac{kT}{q}\ln\left[\frac{p_o(x_P)}{p_o(-x_N)}\right] \tag{3.93}$$

Since we have assumed nondegeneracy, $p_o(x_P) = N_{\mathrm{A}}$ and $p_o(-x_N) = n_{\mathrm{i}}^2/N_{\mathrm{D}}$. Therefore,

$$V_{\mathrm{bi}} = \frac{kT}{q}\ln\left[\frac{N_{\mathrm{D}}N_{\mathrm{A}}}{n_{\mathrm{i}}^2}\right]. \tag{3.94}$$

Figure 3.14 shows the equilibrium energy band diagram, electric field, and charge density for a simple abrupt *pn*-junction silicon diode in the vicinity of the depletion region. The conduction bandedge is given by $E_{\mathrm{C}}(x) = E_0 - q\phi(x) - \chi$, the valence bandedge

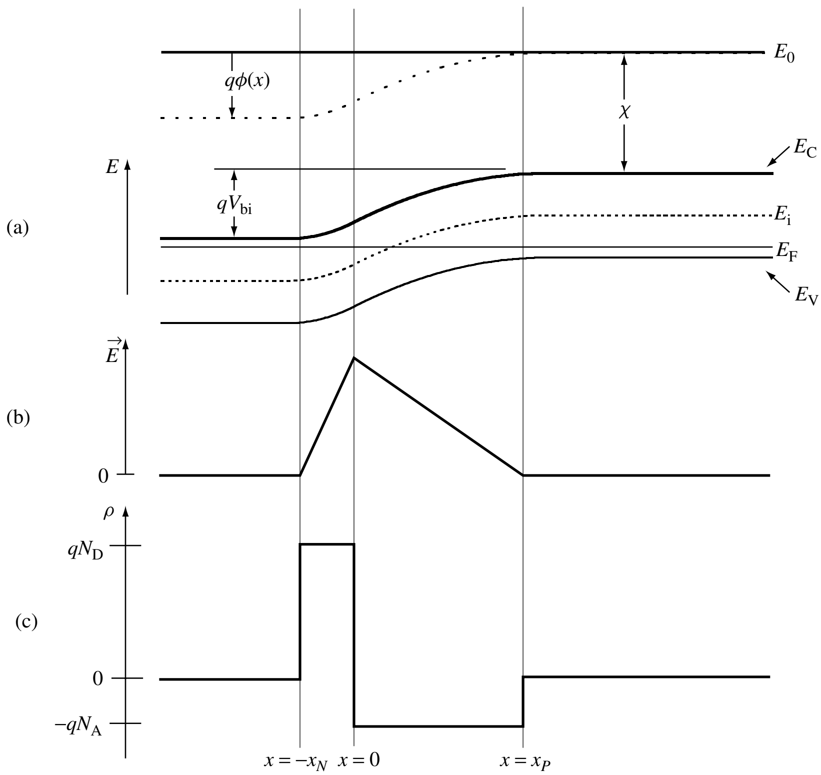

Figure 3.14 Equilibrium conditions in a solar cell: (a) energy bands; (b) electric field; and (c) charge density