simplifying assumptions, which include (1) transparent zero-resistance tunnel-junction interconnects, (2) no reflection losses, (3) no series-resistance losses, and (4) junctions that collect every absorbed photon, and whose current–voltage (J–V) curves are described by the ideal ($n = 1$) diode equation. Later, we relax assumption (2) to analyze the effect of antireflection coatings; the relaxation of the other assumptions is straightforward, as well. It should be noted that high-quality III-V cells have achieved 90% of these predicted efficiencies.

9.5.2 Top and Bottom Subcell QE and J_{SC}

The short-circuit current density (J_{SC}) of each subcell is determined by the quantum efficiency of the subcell, $QE(\lambda)$, and by the spectrum of light incident on that cell $\Phi_{inc}(\lambda)$ in the usual way:

$$J_{SC} = \mathrm{e}\int_0^\infty QE(\lambda)\Phi_{inc}(\lambda)\,\mathrm{d}\lambda \tag{9.1}$$

The QE for an ideal cell of finite base thickness x_b, emitter thickness x_e, and depletion width W (for a total thickness $x = x_e + W + x_b$,) is given by the standard equations [19]

$$QE = QE_{emitter} + QE_{depl} + \exp[-\alpha(x_e + W)]QE_{base} \tag{9.2}$$

where

$$QE_{emitter} = f_\alpha(L_e)\left(\frac{\ell_e + \alpha L_e - \exp(-\alpha x_e)\times [\ell_e\cosh(x_e/L_e) + \sinh(x_e/L_e)]}{\ell_e\sinh(x_e/L_e) + \cosh(x_e/L_e)} - \alpha L_e\exp(-\alpha x_e)\right) \tag{9.3}$$

$$QE_{depl} = \exp(-\alpha x_e)[1 - \exp(-\alpha W)] \tag{9.4}$$

$$QE_{base} = f_\alpha(L_b)\left(\alpha L_b - \frac{\ell_b\cosh(x_b/L_b) + \sinh(x_b/L_b) + (\alpha L_b - \ell_b)\exp(-\alpha x_b)}{\ell_b\sinh(x_b/L_b) + \cosh(x_b/L_b)}\right) \tag{9.5}$$

$$\ell_b = S_b L_b/D_b,\ \ell_e = S_e L_e/D_e,\ D_b = kT\mu_b/\mathrm{e},\ D_e = kT\mu_e/\mathrm{e} \tag{9.6}$$

$$f_\alpha(L) = \frac{\alpha L}{(\alpha L)^2 - 1} \tag{9.7}$$

The photon wavelength dependence is not explicit in these equations, but enters through the wavelength dependence of the absorption coefficient $\alpha(\lambda)$. The quantities $\mu_{b(e)}$, $L_{b(e)}$, and $S_{b(e)}$ are, respectively, the mobility, diffusion length, and surface recombination velocity for the minority carriers in the base (emitter); T is the absolute temperature. Later in this chapter, we will illustrate the use of these equations in the analysis of real-world III-V cells. However, in this section, we shall make the simplifying assumption that each absorbed photon is converted to photocurrent, a remarkably good first approximation