for high-quality III-V junctions. In this case, the QE depends very simply on the total thickness of the device, $x = x_e + W + x_b$, as

$$QE(\lambda) = 1 - \exp[-\alpha(\lambda)x] \tag{9.8}$$

because a fraction $\exp[-\alpha(\lambda)x]$ of the incident light is transmitted through the cell instead of being absorbed. [Although this last equation is self-evident, it can also be deduced from equations (9.2)–(9.5) by setting $S = 0$, $L \gg x$, and $L \gg 1/\alpha$.]

For sub–band gap photons, $\alpha(\lambda) = 0$, and thus $\exp[-\alpha(\lambda)x] = 1$. The light Φ_{inc} incident on the top cell is simply the solar spectrum, Φ_S. In contrast, the light hitting the bottom cell is filtered by the top cell, so that the bottom cell sees an incident spectrum $\Phi_S \exp[-\alpha_t(\lambda)x_t]$, where x_t and $\alpha_t(\lambda)$ are the top-cell thickness and absorption coefficient, respectively. Assuming that the bottom cell is thick enough to absorb essentially all of the above band gap photons incident on it, we conclude that the short-circuit current densities of the top cell, J_{SCt}, and the bottom cell, J_{SCb}, are given by

$$J_{SCt} = e\int_0^{\lambda_t} (1 - \exp[-\alpha_t(\lambda)x_t])\Phi_S(\lambda)\, d\lambda,\ J_{SCb} = e\int_0^{\lambda_b} \exp[-\alpha_t(\lambda)x_t]\Phi_S(\lambda)\, d\lambda \tag{9.9}$$

where $\lambda_b = hc/E_{gb}$ and $\lambda_t = hc/E_{gt}$ are the wavelengths corresponding to the band gaps of the bottom and top cells, respectively. The lower limit on the J_{SCb} integral is 0, not λ_t, because unless the top cell is infinitely thick, it will transmit some short-wavelength photons to the bottom cell. Because the bottom subcell is filtered by the top subcell, J_{SCb} depends on both E_{gb} and E_{gt}, whereas J_{SCt} depends only on E_{gt}. Equation (9.10) shows this dependence with special clarity in the case of an infinitely thick top cell. In this case, $\exp[-\alpha_t(\lambda)x_t] = 0$ for all photon energies above E_{gt}, so that the J_{SC} equations become

$$J_{SCt} = e\int_0^{\lambda_t} \Phi_S(\lambda)\, d\lambda,\ J_{SCb} = e\int_{\lambda_t}^{\lambda_b} \Phi_S(\lambda)\, d\lambda \tag{9.10}$$

9.5.3 Multijunction *J*–*V* Curves

For any set of m series-connected subcells (or, indeed, any sort of two-terminal element or device) whose individual current–voltage (J–V) curves are described by $V_i(J)$ for the ith device, the J–V curve for the series-connected set is simply

$$V(J) = \sum_{i=1}^{m} V_i(J) \tag{9.11}$$

that is, the voltage at a given current is equal to the sum of the subcell voltages at that current. Each individual subcell will have its own maximum-power point $\{V\mathrm{mp}_i, J\mathrm{mp}_i\}$, which maximizes $J \times V_i(J)$. However, in the series-connected multijunction connection of these subcells, the currents through each of the subcells are constrained to have the same value, and therefore *each subcell will be able to operate at its maximum-power point only if* $J\mathrm{mp}_i$ *is the same for all the subcells*, that is, $J\mathrm{mp}_1 = J\mathrm{mp}_2 = \cdots = J\mathrm{mp}_m$. If this is the case, then the maximum power output of the combined multijunction device is