In the second case, the absorption coefficient is α = 10 cm ...

then, in which 90 percent of the incident flux is absorbed, is

$$d = \frac{1}{10^4} \ln\left(\frac{1}{0.1}\right) = 2.30 \times 10^{-4} \text{ cm} = 2.30\ \mu\text{m}$$

■ **Comment**

As the incident photon energy increases, the absorption coefficient increases rapidly, so that the photon energy can be totally absorbed in a very narrow region at the surface of the semiconductor.

■ **EXERCISE PROBLEM**

**Ex 14.1** Consider a slab of silicon 5 $\mu$m thick. Determine the percentage of photon flux that will pass through the slab if the photon wavelength is (*a*) $\lambda = 0.8\ \mu$m and (*b*) $\lambda = 0.6\ \mu$m.

[Ans. (*a*) 60.7%; (*b*) 10.5%]

The relation between the bandgap energies of some of the common semiconductor materials and the light spectrum is shown in Figure 14.5. We may note that silicon and gallium arsenide will absorb all of the visible spectrum, whereas gallium phosphide, for example, will be transparent to the red spectrum.

## 14.1.2 Electron–Hole Pair Generation Rate

We have shown that photons with energy greater than $E_g$ can be absorbed in a semiconductor, thereby creating electron–hole pairs. The intensity $I_\nu(x)$ is in units of

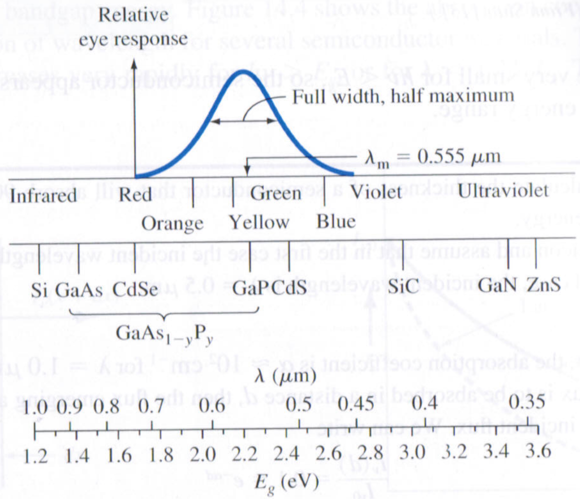


**Figure 14.5** | Light spectrum versus wavelength and energy. Figure includes relative response of the human eye.
(*From Sze [18].*)

...ume that one absorbed photon ... the generation rate of electron–hole pairs is

$$g' = \frac{\alpha I_\nu(x)}{h\nu} \tag{14.6}$$

...ch is in units of #/cm$^3$-s. We may note that the ratio $I_\nu(x)/h\nu$ is the photon flux. If ... the average, one absorbed photon produces less than one electron–hole pair, then ...ation (14.6) must be multiplied by an efficiency factor.

**Objective:** Calculate the generation rate of electron–hole pairs given an incident intensity of photons.

Consider gallium arsenide at $T = 300$ K. Assume the photon intensity at a particular p... $I_\nu(x) = 0.05$ W/cm$^2$ at a wavelength of $\lambda = 0.75\ \mu$m. This intensity is typical of sunli... for example.

■ **Solution**

The absorption coefficient for gallium arsenide at this wavelength is $\alpha \approx 0.9 \times 10^4$ cm$^{-1}$. The photon energy, using Equation (14.1), is

$$E = h\nu = \frac{1.24}{0.75} = 1.65 \text{ eV}$$

Then, from Equation (14.6) and including the conversion factor between joules and e... have, for a unity efficiency factor,

$$g' = \frac{\alpha I_\nu(x)}{h\nu} = \frac{(0.9 \times 10^4)(0.05)}{(1.6 \times 10^{-19})(1.65)} = 1.70 \times 10^{21} \text{ cm}^{-3}\text{-s}^{-1}$$

If the incident photon intensity is a steady-state intensity, then, from Chapter 6, the ...state excess carrier concentration is $\delta n = g'\tau$, where $\tau$ is the excess minority carrier li... If $\tau = 10^{-7}$ s, for example, then

$$\delta n = (1.70 \times 10^{21})(10^{-7}) = 1.70 \times 10^{14} \text{ cm}^{-3}$$

■ **Comment**

This example gives an indication of the magnitude of the electron–hole generation rat... magnitude of the excess carrier concentration. Obviously, as the photon intensity d... with distance in the semiconductor, the generation rate also decreases.

■ **EXERCISE PROBLEM**

**Ex 14.2** A photon flux with an intensity of $I_{\nu 0} = 0.10$W/cm$^2$ and at a wavelength of $\lambda = 1\ \mu$m is incident on the surface of silicon. Neglecting any reflection ..., the surface, determine the generation rate of electron–hole pairs at a depth ... the surface, (*a*) $x = 5\ \mu$m and (*b*) $x = 20\ \mu$m from the surface.

[Ans. (*a*) $4.79 \times 10^{19}$ cm$^{-3}$-s$^{-1}$; (*b*) $4.13 \times 10^{19}$ cm$^{-3}$-s$^{-1}$]