**11.1.6** At room temperature, GaAs has an electron affinity of $e\chi = 4.07$ eV and a bandgap of $E_g = 1.424$ eV.

(a) Find the work function, the threshold photon energy, and the threshold wavelength for a lightly doped n-type GaAs crystal that has a Fermi level at $E_F = E_c - 300$ meV.

(b) Find the work function, the threshold photon energy, and the threshold wavelength for a lightly doped p-type GaAs crystal that has a Fermi level at $E_F = E_v +$ 300 meV.

**11.1.7** At room temperature, GaAs has an electron affinity of $e\chi = 4.07$ eV and a bandgap of $E_g = 1.424$ eV.

(a) Find the work function, the threshold photon energy, and the threshold wavelength for a heavily doped n-type GaAs crystal that has a Fermi level at $E_F = E_c + 300$ meV.

(b) Find the work function, the threshold photon energy, and the threshold wavelength for a ~~lightly~~ doped p-type GaAs crystal that has a Fermi level at $E_F = E_v - 300$ meV.

**11.1.8** The intrinsic electron and hole concentrations of GaAs in thermal equilibrium at room temperature are $n_0 = p_0 = n_i = 2.33 \times 10^{12}$ m$^{-1}$. It has an electron mobility of $\mu_e =$ 0.85 m$^2$ V$^{-1}$ s$^{-1}$ and a hole mobility of $\mu_h = 0.04$ m$^2$ V$^{-1}$ s$^{-1}$. An intrinsic GaAs crystal used as a photoconductor is uniformly illuminated with an optical beam to generate electron–hole pairs for total electron and hole concentrations of $n \approx p \approx 1.0 \times 10^{20}$ m$^{-3}$. Find the dark conductivity and the photoconductivity.

**11.1.9** The intrinsic electron and hole concentrations of Ge in thermal equilibrium at room temperature are $n_0 = p_0 = n_i = 1.95 \times 10^{19}$ m$^{-1}$. It has an electron mobility of $\mu_e =$ 0.39 m$^2$ V$^{-1}$ s$^{-1}$ and a hole mobility of $\mu_h = 0.19$ m$^2$ V$^{-1}$ s$^{-1}$. An intrinsic Ge crystal used as a photoconductor is uniformly illuminated with an optical beam to generate electron–hole pairs. Find the dark conductivity. What are the required concentrations of the photogenerated electrons and holes for the photoconductivity to be 20 times the dark conductivity?

**11.1.10** A Si photodiode at $T = 300$ K has a reverse current of $I_0 = 10$ nA and a realistic diode factor of $a = 1.2$. For the detection of optical signals at the $\lambda = 532$ nm wavelength, its external quantum efficiency is $\eta_e = 0.7$. It is illuminated with an optical signal that has a power of $P_s = 200$ µW at $\lambda = 532$ nm.

(a) If the photodiode is operated in the photoconductive mode with a reverse bias voltage of $V_r = 5$ V, what is the required load resistance for the output voltage to be at least 100 mV?

(b) If the photodiode is operated in the photovoltaic mode with a very large load resistance, what is the output voltage?

(c) What are the output voltages for $P_s = 5$ mW in the photoconductive mode with the load resistance found in (a) and in the photovoltaic mode, respectively?

**11.1.11** A Ge photodiode has a reverse current of $I_0 = 2$ µA and a realistic diode factor of $a =$ 1.1 at $T = 300$ K. Its external quantum efficiency is $\eta_e = 0.54$ for an optical signal at $\lambda = 1.55$ µm. The power of the optical signal varies between 0.5 mW and 5 mW.

(a) The photodiode is operated in the photoconductive mode with a reverse bias voltage of $V_r = 10$ V and a load resistance of $R_L = 50\ \Omega$. What is the range of