Then

$$g_c(1-f_c) = \sqrt{x}\exp\left(\frac{-x}{kT}\right)$$

To find the maximum value

$$\frac{d[g_c(1-f_c)]}{dx} = \frac{d}{dx}\left[\sqrt{x}\exp\left(\frac{-x}{kT}\right)\right] = 0$$

Same as part (a). Maximum occurs at

$$x = \frac{kT}{2} = E_c - E$$

or

$$E = E_c - \frac{kT}{2}$$

4.6

$$\frac{n(E_1)}{n(E_2)} = \frac{\sqrt{E_1 - E_c}\exp\left[\frac{-(E_1 - E_c)}{kT}\right]}{\sqrt{E_2 - E_c}\exp\left[\frac{-(E_2 - E_c)}{kT}\right]}$$

where

$$E_1 = E_c + 4kT \quad \text{and} \quad E_2 = E_c + \frac{kT}{2}$$

Then

$$\frac{n(E_1)}{n(E_2)} = \frac{\sqrt{4kT}}{\sqrt{\frac{kT}{2}}}\exp\left[\frac{-(E_1 - E_2)}{kT}\right]$$

$$= 2\sqrt{2}\exp\left[-\left(4 - \frac{1}{2}\right)\right] = 2\sqrt{2}\exp(-3.5)$$

or

$$\frac{n(E_1)}{n(E_2)} = 0.0854$$

4.7
Computer Plot

4.8

$$\frac{n_i^2(A)}{n_i^2(B)} = \frac{\exp\left(\frac{-E_{gA}}{kT}\right)}{\exp\left(\frac{-E_{gB}}{kT}\right)} = \exp\left[\frac{-(E_{gA} - E_{gB})}{kT}\right]$$

or

$$\frac{n_i(A)}{n_i(B)} = \exp\left[\frac{-(E_{gA} - E_{gB})}{2kT}\right]$$

$$= \exp\left[\frac{-(1-1.2)}{2(0.0259)}\right] = \exp\left[\frac{+0.20}{2(0.0259)}\right]$$

or

$$\frac{n_i(A)}{n_i(B)} = 47.5$$

4.9
Computer Plot

4.10

$$E_{Fi} - E_{midgap} = \frac{3}{4}kT\ln\left(\frac{m_p^*}{m_n^*}\right)$$

Silicon: $m_p^* = 0.56m_0$, $m_n^* = 1.08m_0$

$$E_{Fi} - E_{midgap} = -0.0128\ eV$$

Germanium: $m_p^* = 0.37m_0$, $m_n^* = 0.55m_0$

$$E_{Fi} - E_{midgap} = -0.0077\ eV$$

Gallium Arsenide: $m_p^* = 0.48m_0$, $m_n^* = 0.067m_0$

$$E_{Fi} - E_{midgap} = +0.038\ eV$$

4.11

(a) $$E_{Fi} - E_{midgap} = \frac{3}{4}kT\ln\left(\frac{m_p^*}{m_n^*}\right)$$

$$= \frac{3}{4}(0.0259)\ln\left(\frac{1.4}{0.62}\right) \Rightarrow$$

$$E_{Fi} - E_{midgap} = +0.0158\ eV$$

(b)

$$E_{Fi} - E_{midgap} = \frac{3}{4}(0.0259)\ln\left(\frac{0.25}{1.10}\right) \Rightarrow$$

$$E_{Fi} - E_{midgap} = -0.0288\ eV$$

4.12

$$E_{Fi} - E_{midgap} = \frac{1}{2}(kT)\ln\left(\frac{N_v}{N_c}\right)$$

$$= \frac{1}{2}(kT)\ln\left(\frac{1.04\times10^{19}}{2.8\times10^{19}}\right) = -0.495(kT)$$

Introduction To Semiconductor Devices Solution Manual Neamen

Christian G. Meyer

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