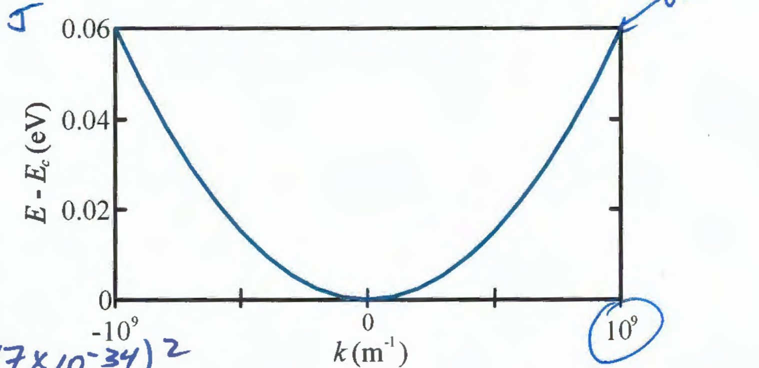
EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 3 (Spring 2025)

Name Key A

Instructions: Open book/notes. Place answers in indicated spaces and show all work for credit.

The energy curve shown below is for an electron in the conduction band of Grubbium (newly discovered semiconductor). Determine the effective mass m_G^* of this electron (kg & in terms of the rest mass of a free electron m_0). At 290 K, calculate the energy $\Delta E = 2.25 k_B T$ (J & eV). Then, determine the total number (#/cm^3) of energy states in Grubbium for $E_c \le E \le E_c + \Delta E$.



(3.44) $E - E_c \simeq C_a k^2$ ← convert to J

$(0.06\,eV)(1.602176634^{-19}) = C_a (10^9)^2$

$\hookrightarrow C_a = 9.61306 \times 10^{-39}\ J \cdot m^2$

(3.47) $m_G^* = \dfrac{\hbar^2}{2C_a} = \dfrac{(1.054571817 \times 10^{-34})^2}{2(9.61306 \times 10^{-39}}$

$m_G^* = \underline{5.78443 \times 10^{-31}\ kg} \left(\dfrac{1\,m_0}{9.1093837 \times 10^{-31}\ kg}\right) = \underline{0.6350\ m_0}$

$\Delta E = 2.25 k_B T = 2.25 (1.380649 \times 10^{-23}\ J/K)(290\ K) = \underline{9.008735 \times 10^{-21}\ J}$

$\div 1.6021766 \times 10^{-19} = \underline{0.056228\ eV}$

(3.72) & Ex 3.4 $N_{tot} = \int_{E_c}^{E_c+\Delta E} g_c(E)\,dE = \int_{E_c}^{E_c+\Delta E} \dfrac{4\pi (2m_n^*)^{3/2}}{h^3} \sqrt{E - E_c}\,dE$

$= \dfrac{4\pi (2m_G^*)^{3/2}}{h^3}\ \tfrac{2}{3} (E_c + \Delta E - E_c)^{3/2} \leftarrow \Delta E^{3/2}$

$= \dfrac{4\pi\ 2^{3/2} (5.78443 \times 10^{-31})^{3/2}}{(6.62607015 \times 10^{-34})^3}\ \tfrac{2}{3} (9.008735 \times 10^{-21})^{3/2}$

$= 3.063953 \times 10^{25}\ \#/m^3 = 3.06395 \times 10^{19}\ \#/cm^3$

$m_G^* =$ $\underline{5.78443 \times 10^{-31}\ kg}$ $=$ $\underline{0.635\ m_0}$ $\Delta E =$ $\underline{9.0087 \times 10^{-21}\ J}$ $=$ $\underline{0.05623\ eV}$

$N_{tot} =$ $\underline{3.06395 \times 10^{19}\ \#/cm^3}$

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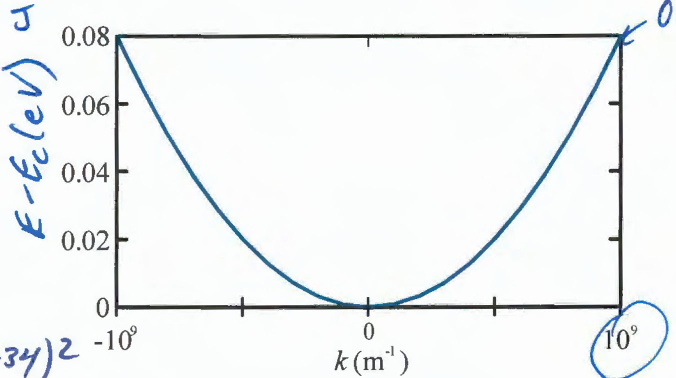
Name Key B

Instructions: Open book/notes. Place answers in indicated spaces and show all work for credit.

The energy curve shown below is for an electron in the conduction band of Rockerium (newly created semiconductor). Determine the effective mass m_R* of this electron (kg & in terms of the rest mass of a free electron m_0). At 275 K, calculate the energy $\Delta E = 2.56k_BT$ (J & eV). Then, determine the total number (#/cm^3) of energy states in Rockerium for $E_c \le E \le E_c + \Delta E$.



(3.44) $E - E_c = C_b k^2$ ← convert to J

$(0.08\,eV)(1.602176634\times10^{-19}) = C_b (10^9)^2$

$\hookrightarrow C_b = 1.2817413\times10^{-38}\ J\cdot m^2$

(3.47) $m_R^* = \dfrac{\hbar^2}{2C_b} = \dfrac{(1.054571817\times10^{-34})^2}{2(1.2817413\times10^{-38})}$

$= \underline{4.3383236\times10^{-31}\ kg}\left(\dfrac{m_0}{9.1093837\times10^{-31}\,kg}\right) = \underline{0.47625\ m_0}$

$\Delta E = 2.56(1.380649\times10^{-23}\ J/K)(275\ K) = \underline{9.719769\times10^{-21}\ J}$

$= 2.56(8.617333\times10^{-5}\ eV/K)(275) = \underline{0.060666\ eV}$

(3.72) + Ex. 3.4

$N_{TOT} = \int_{E_c}^{E_c+\Delta E} g_c(E)\,dE = \int_{E_c}^{E_c+\Delta E} \dfrac{4\pi(2m_n^*)^{3/2}}{h^3}\sqrt{E-E_c}\,dE$

$= \dfrac{4\pi(2m_n^*)^{3/2}}{h^3}\,\tfrac{2}{3}(E-E_c)^{3/2}\Big|_{E_c}^{E_c+\Delta E} = \dfrac{4\pi(2m_n^*)^{3/2}}{h^3}\,\tfrac{2}{3}\,\Delta E^{3/2}$

$= \dfrac{4\pi\, 2^{3/2}(4.3383236\times10^{-31})^{3/2}}{(6.62607015\times10^{-34})^3}\,\tfrac{2}{3}(9.719769\times10^{-21})^{3/2}$

$= 2.230295\times10^{25}\ \#/m^3 = \underline{2.2303\times10^{19}\ \#/cm^3}$

m_R^* = 4.33832×10^{-31} kg = $0.47625\ m_0$ ΔE = 9.71977×10^{-21} J = 0.06067 eV

N_{tot} = $2.2303\times10^{19}\ \#/cm^3$