EE 362 Electronic, Magnetic, & Optical Properties of Materials
Quiz 3 (Spring 2024)

Name Key A

Instructions: Open book & notes. Place answers in indicated spaces. Show all work. Use 4-5 significant figures.

A tin selenide (SnSe) semiconductor has a bandgap of 0.9 eV. At 325 K, assume the Fermi energy level is at midgap. First, find k_BT (eV). Then, calculate the energy difference $\Delta E_1 = E_c + 0.6k_B\text{T} - E_F$ (eV). Finally, determine the probability that a state at energy $E_F + \Delta E_1$ is occupied by an **electron** (unitless).

$$k_B T = \left(8.617333 \times 10^{-5} \frac{eV}{K}\right)(325\,K) = \underline{0.028006\ eV}$$

$$\Delta E_1 = E_c - E_F + 0.6 k_B T = E_c - \left(\underset{\substack{\uparrow \\ \text{midgap}}}{\frac{E_c + E_v}{2}}\right) + 0.6 k_B T$$

$$= \frac{E_c}{2} - \frac{E_v}{2} + 0.6 k_B T \quad \text{but } E_g = E_c - E_v$$

$$= \frac{E_g}{2} + 0.6 k_B T = \frac{0.9}{2} + 0.6(0.028006)$$

$$= \underline{0.466804\ eV}$$

$$(3.79) \quad f_F(E) = \frac{1}{1 + e^{(E - E_F)/k_B T}}$$

$$\text{where } E - E_F = (E_F + \Delta E_1) - E_F = \Delta E_1$$

$$f_F(E_F + \Delta E_1) = \frac{1}{1 + e^{0.466804/0.028006}} \simeq e^{-\frac{0.466804}{0.028006}} \quad \text{(M-B approx)}$$

$$= \underline{\underline{5.77123 \times 10^{-8}}}$$

k_BT = 0.028006 eV ΔE_1 = 0.466804 eV $\text{prob}_{e,\Delta E1}$ = 5.7712×10^{-8}

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Name Key B

Instructions: Open book & notes. Place answers in indicated spaces. Show all work. Use 4-5 significant figures.

A magnesium silicide (Mg_2Si) semiconductor has a bandgap of 0.79 eV. At 275 K, the Fermi energy level is at midgap. First, find k_BT (eV). Then, calculate the energy difference $\Delta E_2 = E_c + 0.3k_B\text{T} - E_F$ (eV). Finally, determine the probability that a state at energy $E_F + \Delta E_2$ is occupied by an **electron** (unitless).

$$k_BT = \left(8.617333\times10^{-5}\,\frac{eV}{K}\right)(275K) = \underline{0.023698\ eV}$$

$$\Delta E_2 = E_c - E_F + 0.3k_BT = E_c - \left(\frac{E_c+E_v}{2}\right) + 0.3k_BT$$

← midgap

$$= \frac{E_c}{2} - \frac{E_v}{2} + 0.3k_BT \quad \text{where } E_g = E_c - E_v$$

$$= \frac{E_g}{2} + 0.3k_BT = \frac{0.79}{2} + 0.3(0.0237)$$

$$\underline{\Delta E_2 = 0.402109\ eV}$$

$$(3.79)\quad f_F(E) = \frac{1}{1+e^{(E-E_F)/k_BT}}$$

$$\text{where } E - E_F = (E_F + \Delta E_2) - E_F = \Delta E_2$$

$$f_F(E_F+\Delta E_2) = \frac{1}{1+e^{0.40211/0.0237}} \simeq e^{-0.40211/0.0237}$$

(M-B approx.)

$$= \underline{4.27324\times10^{-8}}$$

k_BT = 0.023698eV ΔE_2 = 0.40211 eV prob$_{e,\Delta E2}$ = 4.2732×10^{-8}