PROBLEM 1 (KRANE 32)

IF $E_g = 1.1\,eV$. AT THE BOTTOM OF THE CONDUCTION BAND, WITH $T = 293K$, THE OCCUPATION PROBABILITY IS

a.) $$e^{-E_g/2kT} = e^{\frac{-1.1eV}{2(8.617\cdot10^{-5}eV/K)(293K)}} = \boxed{3.462\cdot10^{-10}}.$$

AT THE TOP OF THE VALENCE BAND, WE HAVE AN OCCUPATION PROBABILITY OF

b.) $$\boxed{1-(3.462\cdot10^{-10})}.$$

Problem 2

Let $E_g = 1.14\,eV$, $m_n^* = 1.06 \cdot m_e$, $m_p^* = .58 \cdot m_e$.

$\boxed{a.)}$ At $T = 300K$

$$n_n = \frac{1}{\sqrt{2}} \left(\frac{m_n^* kT}{\pi \hbar^2} \right)^{3/2} \exp\left(-\frac{E_c - E_F}{k_B T} \right)$$

Note

$E_c - E_F = \frac{E_g}{2}$

For intrinsic semi conductor

$$= \frac{1}{\sqrt{2}} \left(\frac{1.06\, m_e\, kT}{\pi\, \hbar^2} \right)^{3/2} \exp\left(-\frac{E_g}{2kT} \right)$$

$$= \frac{1}{\sqrt{2}} \left(\frac{1.06\, M_e c^2 \cdot kT}{\pi (\hbar c)^2} \right)^{3/2} \exp\left\{ -\frac{E_g}{2kT} \right\}$$

$$= \frac{1}{\sqrt{2}} \left(\frac{1.06\, (511{,}000\, \cancel{eV})(.02525\, \cancel{eV})}{\pi\, (197\, \cancel{eV} \cdot nm)^2} \right)^{3/2} \exp\left\{ -\frac{1.14\,eV}{2(.02525\,eV)} \right\}$$

$$= 4.1732 \cdot 10^{-12} \left(nm^{-2} \right)^{3/2} = \boxed{4.1732 \cdot 10^{-12}\ nm^{-3}}$$

$\boxed{c.)}$ At $T = 77\,K$

$$n_n = \frac{1}{\sqrt{2}} \left(\frac{1.06\, (511{,}000\, eV)(.0066\, eV)}{\pi\, (197\, eV\, nm)^2} \right)^{3/2} \exp\left\{ -\frac{1.14}{2(0.0066\,eV)} \right\}$$

$$= \boxed{1.11 \cdot 10^{-40}\ nm^{-3}}$$

$\boxed{\text{b.)}}$ AT $T = 300\,K$

$$n_p = \frac{1}{\sqrt{2}}\left(\frac{0.58\, m_e c^2 kT}{\pi (\hbar c)^2}\right)^{3/2} \exp\left\{-\frac{E_g}{2kT}\right\}$$

$$= \frac{1}{\sqrt{2}}\left(\frac{0.58\,(511000\,eV)(.02525\,eV)}{\pi(197\,eV\,nm)^2}\right)^{3/2} \cdot \exp\left\{\frac{-1.14\,eV}{2(0.02525\,eV)}\right\}$$

$$= \boxed{1.689 \cdot 10^{-12}\ nm^{-3}}$$

$\boxed{\text{d.)}}$ AT $T = 77\,K$

$$n_p = \frac{1}{\sqrt{2}}\left(\frac{.58\,(511000\,eV)(.0066\,eV)}{\pi(197\,eV\,nm)^2}\right)^{3/2} \exp\left\{\frac{-1.14\,eV}{2(0.0066)}\right\}$$

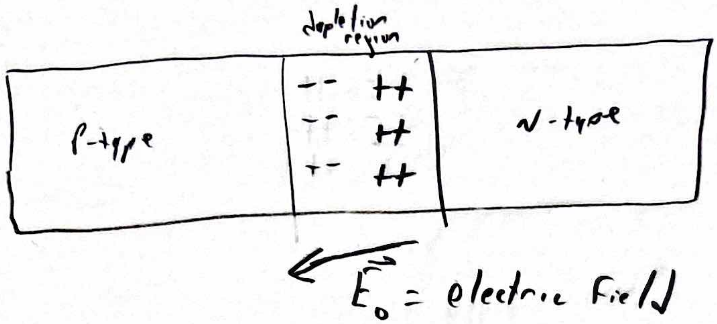
$$= \boxed{4.469 \cdot 10^{-41}\ nm^{-3}}$$

e.) $n_{bulk} = 10^{29}\,m^{-3} = 10^{29}\,(nm \cdot 10^{9})^{-3} = 10^{29} \cdot 10^{27}\,nm^{-3} = 100\,nm^{-3}$

THEREFORE $n_{bulk} \gg n_n + n_p$. BOTH $n_n + n_p$ ARE HIGHLY TEMP DEPENDENT, AS EXPECTED FROM THE $e^{\frac{-E_g}{kT}}$ TERM.

PROBLEM 3

a.)



b.) THE FERMI ENERGY IS ROUGHLY THE ENERGY OF THE DONOR STATE FOR THE n-type AND THE ACCEPTOR STATE FOR THE p-type. SO THE DIFFERENCE SHOULD BE

$$1.14\,eV - .054\,eV - .045\,eV = 1.041\,eV.$$

c.) 1.041 V.

PROBLEM 4 (KRANE 33)

LET $E_g = 0.66 eV$. SO PROBABILITY OF OCCUPATION

IS $e^{-\frac{.66 eV}{2 \cdot 0.0259 eV}} = 2 \cdot 10^{-6}$.

NOW

$3 \cdot 2 \cdot 10^{-6} = 6 \cdot 10^{-6}$

NEED TO REPLACE $(6-2) \cdot 10^{-6} = \boxed{4 \cdot 10^{-6}}$

TIMES THE TOTAL ATOMS TO ACHIEVE A

3 X INCREASE IN CONDUCTION BAND

OCCUPENCY.

PROBLEM 5 (KRANE # 57)

a.) ASSUMING ALL THE ENERGY OF THE 662,000 eV GAMMA RAY IS ABSORBED BY ELECTRONS JUMPING THE BAND GAP, WE HAVE

$$N = \frac{622{,}000}{.66} = \boxed{10^6}$$

EXCITED ELECTRONS.

b.) THIS GIVES VARIANCE OF

$$\sqrt{N} = \left(10^6\right)^{1/2} = 10^3$$

$$\& \quad \frac{\sqrt{N}}{N} = \frac{10^3}{10^6} = \boxed{10^{-3}}$$

c.) VARIATION IN MEASURED ENERGY SHOULD BE

$$10^{-3} \cdot \left|662{,}000\, eV\right| = \boxed{662\, eV}\,.$$

Problem 6

$$\int_{E_c}^{\infty} n(E)\,dE = \int_{E_c}^{\infty} \frac{\sqrt{2}\,(m_n^*)^{3/2} V}{\pi^2 \hbar^3} \frac{\sqrt{E-E_c}}{e^{(E-E_F)/kT}+1}\,dE$$

$$= \frac{V\sqrt{2}\,(m_n^*)^{3/2}}{\pi^2 \hbar^3} \int_{E_c}^{\infty} \frac{\sqrt{E-E_c}}{e^{(E-E_F)/kT}}\,dE \qquad \boxed{e^{(E-E_F)/kT} \gg 1}$$

Let $x = (E-E_c)/kT \implies \sqrt{E-E_c} = \sqrt{kT}\cdot\sqrt{x}$.

Now

$$\int_{E_c}^{\infty} n(E)\,dE = \frac{V\sqrt{2}\,(m_n^*)^{3/2}}{\pi^2\hbar^3}\int_0^{\infty} \frac{\sqrt{x}}{e^{(E_c-E_F)/kT}\cdot e^{x}}\,dx \qquad dE = kT\,dx$$

$$= \frac{V\sqrt{2}\,(m_n^*)^{3/2}}{\pi^2\hbar^3} \cdot \frac{\sqrt{\pi}}{2} \cdot \frac{1}{\exp\left\{\frac{(E_c-E_F)}{kT}\right\}}$$

$$= \frac{V}{4}\left(\frac{2m_n^* kT}{\pi\hbar^2}\right)^{3/2} \exp\left(-\frac{(E_c-E_F)}{kT}\right).$$