TASK 13.2

$$V_{bi} = |\phi_{Fn}| + |\phi_{Fp}| = \frac{k_B T}{e} \ln\left(\frac{p_0 n_0}{n_i^2}\right)$$

Assuming that at room temperature, $n_0 = N_d$ and $p_0 = N_a$

$$V_{bi} = 0.0259 \ln\left(\frac{(1\times10^{18})(4\times10^{18})}{(1.5\times10^{10})^2}\right) = 0.97\text{ V}$$

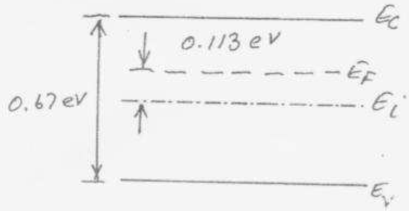
TASK 13.3

450 K.

SLIDE 114

[redacted] $\Rightarrow n_i \simeq 2.5\times10^{13}\ cm^{-3}$ at 300K

a)



$N_D = 6\times10^{15}\ cm^{-3}$

$N_A = 4\times10^{15}\ cm^{-3}$

$\Rightarrow$ n-type and

$n = N_D - N_A = 2\times10^{15}\ cm^{-3}$

$$E_F - E_i = kT \ln n/n_i = 0.02586 \times \ln \frac{2\times10^{15}}{2.5\times10^{13}} = 0.113\text{ eV}$$

b) At 450 K, $n_i \simeq 6.5\times10^{15}\ cm^{-3}$ which is larger than our doping densities! So we have to use the "full" formula:

$$n = \frac{N_D - N_A}{2} + \sqrt{\left(\frac{N_D - N_A}{2}\right)^2 + n_i^2}$$

$$n = 7.58\times10^{15}\ cm^{-3}$$

$$p = n_i^2/n = 5.58\times10^{15}\ cm^{-3}$$

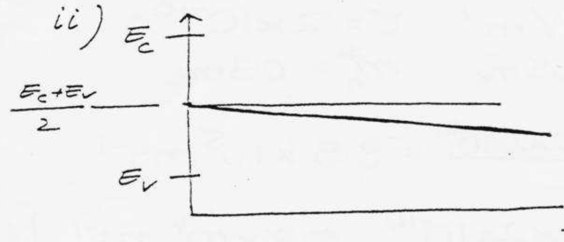
TASK 13.4

5 i) $n_i^2 = N_c N_v \exp -\frac{E_g}{kT}$

$= 10^{19} \cdot 6 \cdot 10^{18} \exp -\frac{660}{26} = 5.67 \cdot 10^{26}\ cm^{-6}$

$n_i = 2.38 \cdot 10^{+13}\ cm^{-3}$

ii)



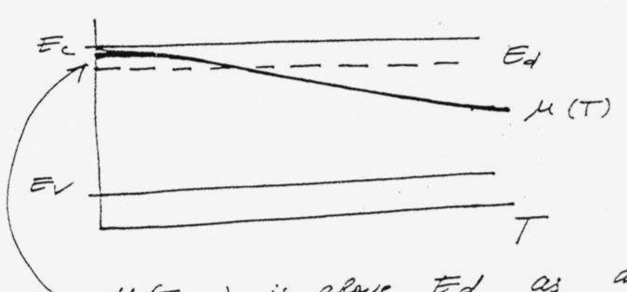
As $\mu = \frac{E_c+E_v}{2} + \frac{1}{2} kT \ln \frac{N_v}{N_c}$ and $N_c > N_v$

iii) This is a donor. As has 5 valence electrons, 4 will contribute to the covalent bonding with Ge, the 5th will be bound to As^- ion.

iv) As $kT > E_i$ all electrons are ionised. The Fermi level lies below E_d.

$n = N_c \exp\left[\frac{-(E_c-\mu)}{kT}\right]$ and $n \simeq N_d$

Hence $E_c - \mu = kT \ln \frac{N_c}{N_d} = 26 \ln \frac{10^{19}}{10^{15}} = 239_{meV}$



$\mu(T=0)$ is above E_d as all the electrons are on donors.