$\frac{kT}{e} = 26\,mV$

11) $D_e = \mu kT$

$L_n = \sqrt{D_n \tau}$

$= \sqrt{26\times10^{-3} \times \mu \times \tau}$

$= \sqrt{26\times10^{-3} \times 4000 \times 6\times10^{-10}}$

$= \sqrt{26\times4\times6 \times 10^{-10}}$

$= 10^{-5} \times \sqrt{16\times24}$

$= 10^{-5} \times 24.98$

$= 2.498\times10^{-4}$

$= 24.98\ \mu m$

12) $I = I_0 e^{-\alpha x}$

$0.1 I_0 = I_0 e^{-\alpha x}$

$10 = e^{\alpha x}$

$\ln 10 = \alpha x$

$x = \frac{\ln 10}{\alpha} = 2.303\times10^{-3}\ cm$

Q→14→ Sol→

$I_D = I_S e^{qV_D/nkT}$

$I_D = I_S e^{V_D/nkT/q}$ $n=2$ for si diode

$e^{V_D/(nkT/q)} = \frac{I_D}{I_S}$

$V_D = V_T \ln\left(\frac{I_D}{I_S}\right)$ (const.) $V_T = \frac{V_D}{nkT/q}$

$\therefore V_D \propto \frac{1}{T}$

$\Rightarrow \frac{V_{D2}}{V_{D1}} = \frac{T_1}{T_2}$

$\Rightarrow V_{D2} = \frac{T_1}{T_2} \times V_{D1} = \frac{300}{1300} \times 0.6$

$= \frac{3}{13} \times 0.6 = \frac{1.8}{13} = 0.138V$

$\Delta V = (0.6 - 0.138) = 0.462V$

Q→16→ Sol→ $n_{th} = \frac{J_{th} \tau_r}{e d_{th}}$

$\boxed{J_{th} = \frac{ned}{\tau}} = \frac{1.32 \times 10^{18} \times 10^{-6} m^{-3} \times 1.6 \times 10^{-19} \times 20 \times 10^{-6}}{2.4 \times 10^{-9}}$

$= \frac{1.32 \times 1.6 \times 20}{2.4} \times 10^{-31+18+9}$

$= 10^{-4} \times 17.6$

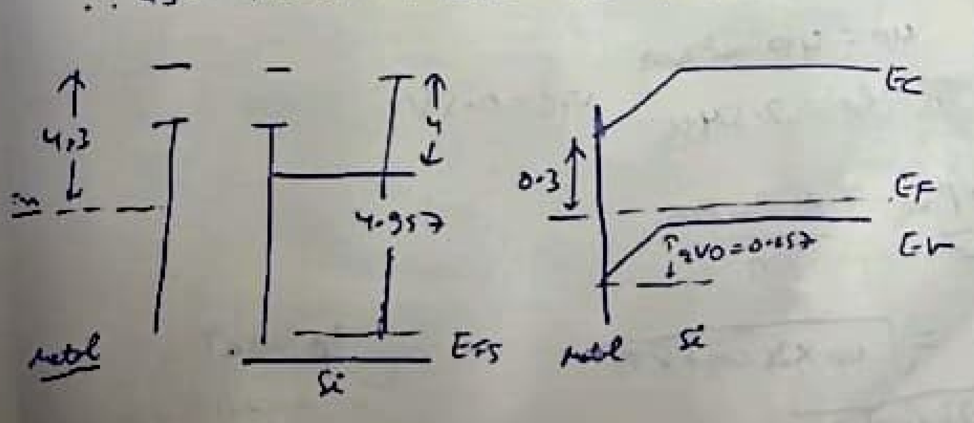
$= 1.76 \times 10^{-3}$

Q→17→ $E_i = E_F + kT \ln\frac{p_0}{n_i}$

$= E_F + 0.0259 \ln\frac{10^{17}}{1.5 \times 10^{10}}$

$= E_F + 0.407 eV$

$\therefore \phi_S = 4+0.55 + 0.407 = 4.957 eV$



$$I_0 = 0.001 \times 1.6\times10^{-19}\left[\frac{\sqrt{1500\times 26\times10^{-3}}\times10^{15}}{\sqrt{2.54}} + \frac{\sqrt{3.30\times 2.6\times10^{-3}}\times10^{15}}{\sqrt{2.54}}\right]$$

$n=2$ for Silicon

$$= 2.18\times10^{-3}A$$

$$I = I_0\left(e^{V/nV_t} - 1\right)$$

$$= 2.18\times10^{-3}\left(e^{0.5/(2\times26\times10^{-3})} - 1\right) = 3.26\times10^{-3}A$$

18:) $I_L = 25mA$ $\quad D_n = 20cm^2/s$ $\quad D_p = 10 cm^2/s$ $\quad A = 1cm^2$

$N_A = 5\times10^{17}$ $\quad N_D = 10^{16}$

$$V_{oc} = 2\times26\times10^{-3}\ln\left(1+\frac{25}{I_0}\right)$$

$$I_0 = 1\left[e\frac{D_n n_p}{L_n} + e\frac{D_p p_n}{L_p}\right) = e\left[\frac{20\times10^{16}}{\sqrt{20\times3\times10^{-7}}} + \frac{10\times5\times10^{17}}{\sqrt{10\times10^{-7}}}\right]$$

$$= e\left[\frac{2\times10^{17}}{\sqrt{6}\times10^{-4}} + \frac{50\times10^{17}}{10^{-4}}\right]$$

$$= 10^{17}\times\frac{e}{10^{-4}}\left[\frac{2}{\sqrt{6}} + 50\right]$$

$$V_{oc} = 52\times10^{-3}\ln\left(1+\frac{25}{8.13\times10^{-3}}\right)$$

$$= \frac{50.82\times1.6\times10^{-15}\times10^{17}}{10^{-4}}$$

$$= 10^2\times 81.312$$

$$= 8.13\times10^3$$

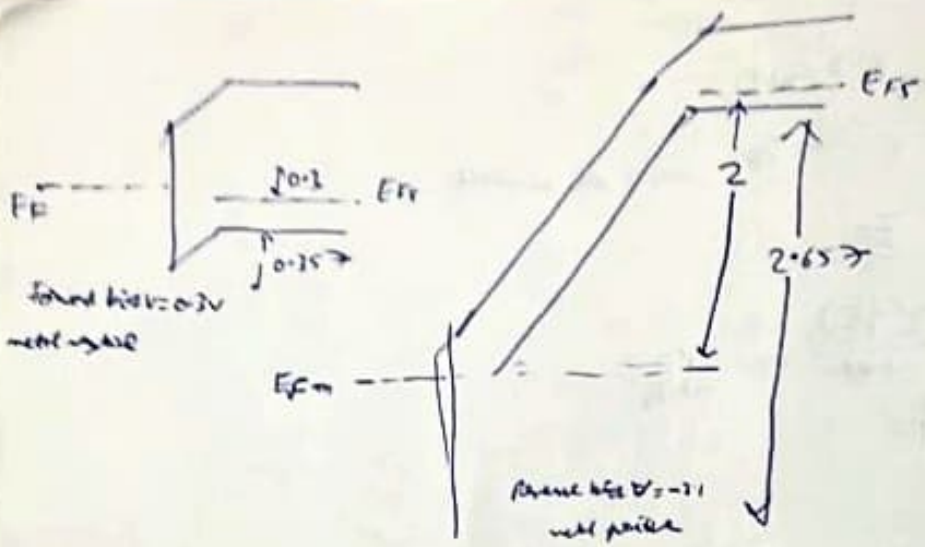
19:) $\eta_{inj} = \frac{J_n}{J_n+J_p} = \frac{1}{1+\left(\frac{J_p}{J_n}\right)}$

$$J_n = \frac{eD_n\times5\times10^{17}}{\sqrt{D_n\times\tau_n}} \qquad J_p = \frac{eD_p\times(5\times10^{16})}{\sqrt{D_p\times\tau_p}}$$

$$\frac{J_p}{J_n} = \sqrt{\frac{D_p}{D_n}}\sqrt{\frac{\tau_n}{\tau_p}}\times\frac{1}{10} = \sqrt{\frac{1}{2}}\times\frac{1}{\sqrt{10}}\times\frac{1}{10}$$

$$= \frac{1}{\sqrt{20\times10}} = \frac{1}{44.7}$$

$$= \frac{1}{1+0.0223} = 0.978$$



20) (a) $A = 0.001\,cm^2$

$N_a = 10^{15}\,cm^{-3}$, $N_d = 10^{17}\,cm^{-3}$, $n_i = 1.5\times10^{10}$

(a) ⇒ Built-in Potential / contact potential ⇒

$$V_0 = \frac{kT}{e}\ln\left(\frac{N_a N_D}{n_i^2}\right)$$

$$= 26\times10^{-3}\ln\left(\frac{10^{15}\times10^{17}}{(1.5\times10^{10})^2}\right)$$

$$= 26\times10^{-3}\ln\left(\frac{10^{32}}{2.25\times10^{20}}\right)$$

$$= 26\times10^{-3}\ln\left(\frac{10^{12}}{2.25}\right)$$

$$= 26\times10^{-3}\times2.303\times(\log 10^{12} - \log 2.25)$$

$$= 26\times2.303\times10^{-3}\times(12 - \log 2.25)$$

$$V_0 = 0.697\,V$$

(b) ⇒ $\mu_n = 1500\,cm^2/Vs$ $\mu_p = 450\,cm^2/Vs$

$\tau_n = \tau_p = 2.5\,\mu s$ $V_{FB} = 0.5\,V$

$$I_0 = \frac{A_s D_p p_{no}}{L_p} + \frac{A_s D_n p_{po}}{L_n}$$

$$L_p = \sqrt{D_p \tau_p} = \sqrt{\mu_p \times 26\times10^{-3}\times\tau_p}$$

$$L_n = \sqrt{\mu_n \times 26\times10^{-3}\times\tau_n}$$

($D_p = \mu_p kT$, $D_n = \mu_n kT$)