FORMULA SHEET – EXAM-4.

$\boxed{E \mid B}$ $\rightarrow$

$$I_{En} = \frac{qAD_n^P}{W_b} n_p e^{qV_{EB}/kT}$$

when $L_p \gg W$

$$I_{Ep} = \frac{qAD_p^n}{W_b} p_n e^{qV_{EB}/kT}$$

$$W = \left[\frac{2\epsilon V_0}{q}\left(\frac{1}{N_a} + \frac{1}{N_d}\right)\right]^{\frac{1}{2}}.$$

$$X_{no} = \frac{W N_a}{N_a + N_d}$$

$$\gamma = \frac{I_{En}}{I_{En} + I_{Ep}} = \frac{I_{En}}{I_E}.$$

$$B = \frac{I_C}{I_{En}} = \frac{I_C}{I_{Ep}}$$ ← Majority ⊕ region carrier

$$I_E = qA\frac{D_p}{L_p}\left[\Delta p_E \coth h \frac{W_b}{L_p}\right].$$

$$\Delta p_E = n_p e^{qV_{EB}/kT}$$

$$\coth h\, y = \frac{1}{y} + \cancel{\frac{y}{3}}\ \frac{y}{3}.$$

$$D = \frac{kT}{q}$$

$$L = \sqrt{\tau D}$$

$$\beta = \frac{B\gamma}{1 - B\gamma}$$

$$\gamma = \left[1 + \frac{W_b n_n \mu_n^P}{L_n^P p_p \mu_p^n}\right]^{-1}$$ p-n-p transistor.

$$B = \operatorname{sech} \frac{W_b}{L_p}.$$

$$\operatorname{sech} y = 1 - \frac{y^2}{2} + \frac{5y^4}{24}.$$

Scanned by CamScanner

$$V_T = \phi_{ms} - \frac{Q_{int}}{C_i} - \frac{Q_d}{C_i} + \phi_S$$

$$C_i = \frac{\varepsilon_0 \varepsilon_{oxide}}{d} \qquad \varepsilon_{oxide\ SiO_2} :- 3.9$$

$$\phi_S = 2 \times \frac{kT}{q} \ln\left(\frac{N_a}{n_i}\right) = 2\phi_F$$

$$W_m = \left[\frac{2\,\varepsilon_{silicon}\,\phi_S}{q\,N_d}\right]^{\frac{1}{2}}$$

$Q_d = -q\,N_a\,W_m$.

$\varepsilon_{silicon} = 11.8 \times 8.854 \times 10^{-14}$

$\varepsilon = 8.854 \times 10^{-14}$.

$\frac{kT}{q} = 0.0259$

$n_i = 1.5 \times 10^{10}$

$$I_D = k_n \left[(V_G - V_T) V_D - \frac{1}{2} V_D^2\right]$$

$\vec{\mu_n}$ = surface electron mobility

$$k_n = \frac{\vec{\mu_n}\, Z\, C_i}{L}$$

$V_D << V_G - V_T$.

$I_D = k_n [(V_G - V_T) V_D)$

$$g = \frac{\partial I_D}{\partial V_D} = k_n (V_G - V_T)$$

$V_D(sat) = V_G - V_T$.

$$I_D = \frac{1}{2} k_n (V_G - V_T)^2$$

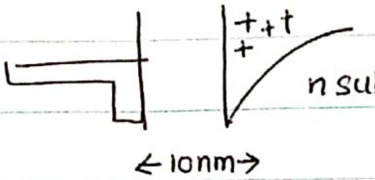
$g_m(sat) = k_n (V_G - V_T)$.

Exam #4 ①

10:32. kxg360.

Krashagi Gupta

① Si MOSFET p-channel.



n subs → $10^{16}/cm^3$

$Q_{inte} = 6 \times 10^{-9}\ C/cm^2$.

$\phi_{ms} = -0.3$ | n ✓ — ①.

$\phi_{ms} = -1.0$ | p

Calc. $V_G = V_T$?

$V_T = \phi_{ms} - \frac{Q_{int}}{C_i} - \frac{Q_d}{C_i}$ (−)

$+2\phi_F$ (−).

$C_i = \frac{\varepsilon_0 \varepsilon_{oxide}}{d} = \frac{8.854 \times \cancel{10^{-14}}\,10^{-8} \times 3.9}{\cancel{10} \times \cancel{10^{-9}} \times \cancel{10^{2}}\,10^{3}} = 3.453 \times 10^{-7}$.

$Q_{int} = 6 \times 10^{-9}\ C/m^2$.

$\frac{Q_{int}}{C_i} = \frac{6 \times \cancel{10^{-9}}\,10^{-2}}{3.453 \times \cancel{10^{-7}}} = 0.0173$ — ②.

$Q_d = q\, N_d\, W_m = (1.602 \times \cancel{10^{-19}})(\cancel{10^{16}})(3 \times \cancel{10^{-5}}\ 10^{-8})$

$= 4.806 \times 10^{-8}\ C$.

$W_m = \left[\frac{2 \times \varepsilon_{silicon}\, \phi_s}{q\, N_d}\right]^{\frac{1}{2}} = \left(\frac{2 \times 11.8 \times 8.854 \times \cancel{10^{-14}}\,10^{-11} \times 0.694}{1.602 \times \cancel{10^{-19}} \times \cancel{10^{16}}\,\cancel{-3}}\right)^{\frac{1}{2}}$

$= 3.0 \times 10^{-5}$ cm

$\frac{Q_d}{C_i} = \frac{4.806 \times \cancel{10^{-8}}\,10^{-1}}{3.453 \times \cancel{10^{-7}}} = 0.139$ — ③.

kxg360

$$\phi_F = \frac{kT}{q} \ln\left(\frac{N_d}{n_i}\right) = 0.0259 \ln\left(\frac{\cancel{10^{16}}\,10^{6}}{1.5\times\cancel{10^{10}}}\right)$$

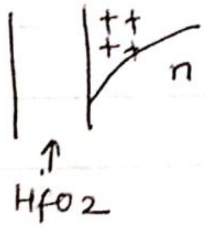
$$\phi_F = 0.3473$$

$$\phi_S = 2\phi_F = 0.694 \text{ —— } 4$$

$$V_T = -0.3 - 0.0173 - 0.139 - 0.694$$

$$= \underline{\underline{1.1504}}$$

Q2. p-channel MOSFET n-type sub



$L = 2\mu m \quad Z = 50\mu m$.

$\vec{\mu_h} = 150\,cm^2/Vs$

$V_T = -0.6V$.

$V_G = -3V$

$V_d = -0.05V$.

$\leftarrow 50nm \rightarrow \quad 50\times10^{-7}\,cm$.

$\varepsilon_r = 25$

1 $$I_D = k_n\left[(V_G - V_T)V_D - \frac{1}{2}V_D^2\right]$$

$$\Rightarrow k_n = \frac{\vec{\mu_h}\,Z\,C_i}{L} = \frac{150\times \overset{25}{\cancel{50}}\,\cancel{\mu}\times 4.42\times10^{-7}}{\cancel{2}\,\cancel{\mu}} = 1.660\times10^{-3}.$$

$$C_i = \frac{\varepsilon_0\varepsilon_r}{d} = \frac{8.854\times10^{-14}\times\cancel{25}}{\cancel{2}\,\cancel{50}\times\cancel{10^{-7}}}\ F \quad 10^{-7}$$

$$= 4.427\times10^{-7}$$

$$I_D = 1.660\times10^{-3}\left[(-3+0.6)(-0.05) - \frac{1}{2}(-0.05)^2\right]$$

$$= 1.971\times10^{-4}\,A.$$

kxg360 (3)

b. $I_D(sat) = \frac{1}{2} k_n (V_G - V_T)^2$

$= \frac{1}{2} \times 1.660 \times 10^{-3} (-3 + 0.6)^2$

$= 4.7808 \times 10^{-3}$.

c). $g = k_n (V_G - V_T)$

$= 1.660 \times 10^{-3} (-3 + 0.6)$.

$= -3.984 \times 10^{-3}$

---

3) Phosp - n type. Base

B

p	n	p.

$\cancel{\alpha = \frac{BY}{1-BY}}$ $\alpha = B\gamma$.

$B = \text{sech} \frac{W_b}{L_p}$. $\gamma = \left[1 + \frac{W_b\, n_n\, \mu_n^p}{L_n^p\, p_p\, \mu_p^n}\right]^{-1}$

$W_b = 2.0 \times 10^{-5}$ cm

$L_p = \sqrt{T_p^n D_p^n}$ $T_p^n = 2500 \times 10^{-12}$.

$L_p^n = \sqrt{2500 \times 10^{-12} \times 10.36} = 1.609 \times 10^{-4}$.

$D_p^n = \frac{kT}{q} \mu_p^n \rightarrow 400$

$= 0.0259 \times 400$

$= 10.36$.

$\frac{W_b}{L_p} = \frac{2.0 \times 10^{-5}\ 10^{-1}}{1.609 \times 10^{-4}} = 0.1243$

$B = 1 - \frac{0.1243^2}{2} = 0.9922$.

Scanned by CamScanner

Kxg360

(4)

P	n	P

$$\gamma = \left[1 + \frac{W_b \; n_n \; \mu_n^P}{L_n^P \; P_p \; \mu_p^n} \right]^{-1}$$

$W_b = 2 \times 10^{-5}$

$n_n = 10^{16}$.

$P_p = 10^{18}$.

$\mu_n^P = 150 \, cm^2 \, v/s$.

$\mu_p^n = 400 \, cm^2 \, v/s$.

$L_n^P = \sqrt{\tau_n^P \times D_n^P}$

$\sqrt{100 \times 10^{-12} \times 3.885} = \underline{\underline{1.971 \times 10^{-5}}}$

$D_n^P = \frac{kT}{q} \mu_n^P$

$= 0.0259 \times 150$

$= 3.885$

$$\gamma = \left[1 + \frac{(2\times \cancel{10^{-5}})(\cancel{10^{16}})(150)}{(1.971\times\cancel{10^{-5}})(\cancel{10^{18}})(400)} \right]^{-1}$$

10^2

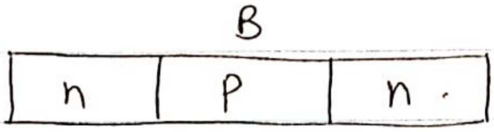
$$= \left[1 + \frac{300}{1.971 \times 4 \times \cancel{10^3}\,10} \right]^{-1} = 0.963 .$$

$$\cancel{\alpha = \frac{0.9922 \times 0.963}{1 - 0.9922 \times 0.963}} = \frac{0.955}{1 - \cancel{0.955}}$$

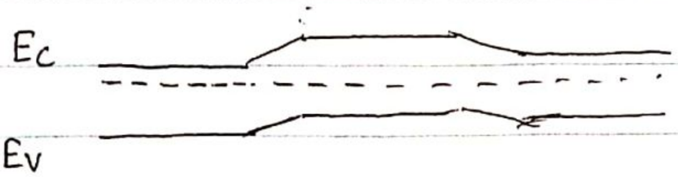
$= \cancel{21.22}$

$\alpha = B\gamma = \underline{\underline{0.955}}$

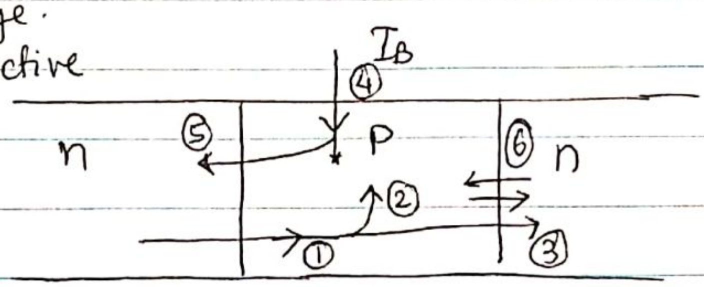
Q. 5.



(a). eq.



(b). mobile charge.
normal Active



BE → F.B.

EC → R.B.

(1) I_{En} flows into p-region & some n electrons recombine In base and the rest reach ~~emitt~~ collector region. shown by ② & ③.

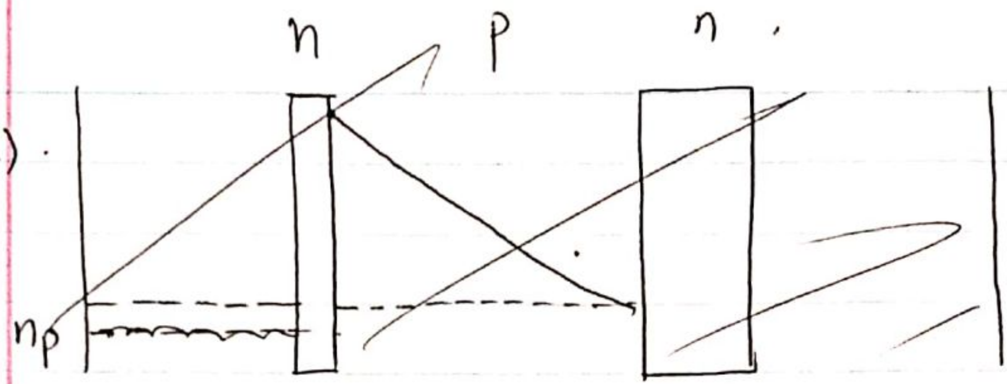
(2) Because of recombination due to ②; holes are externally draw by I_B current, to maintain space charge neutrality. Shown by ④

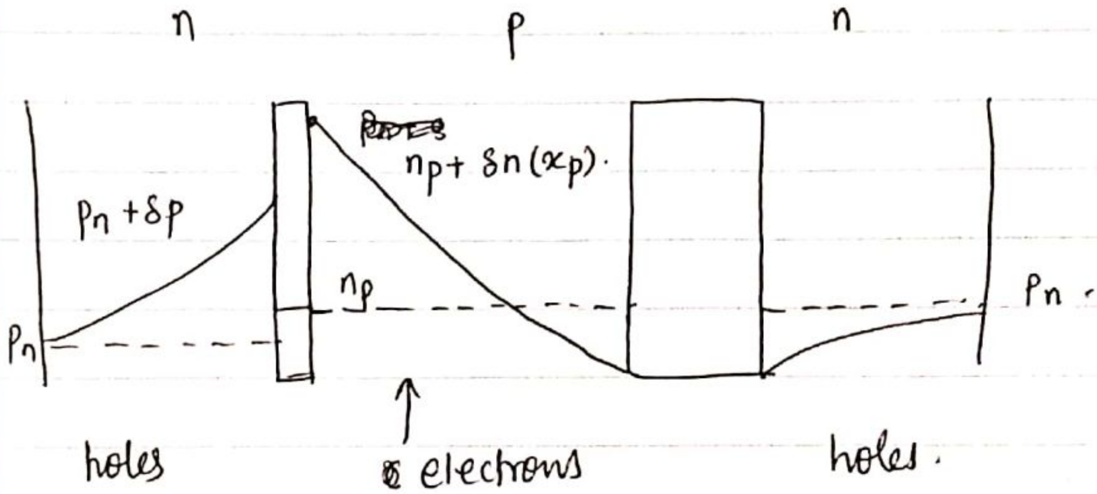
(3) Some of ④ goes ~~to~~ back to emitter due to F.B. condition at that junct Shown by ⑤

(4) A small drift current back & forth happens due to R.B. at collector junction ~~at~~ shown at ⑥.

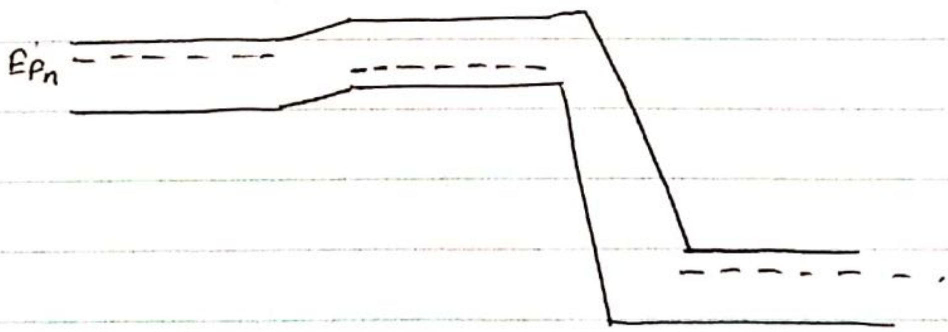
B1

Q5. (C).


n
p
n
n_p


n
p
n
$p_n + \delta p$
$n_p + \delta n(x_p)$
n_p
p_n
p_n
holes
electrons
holes

d.


E_{F_n}

6. solid state swith pnp.

ⓐ

p	n	p
E	B	C

On : Satura V_{EB} & V_{BC} F.B.

Off :- cut off V_{EB} & V_{BC} R-B.

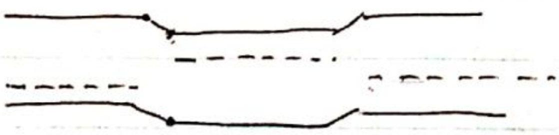
b. On :- Saturation

Off :- cut off.

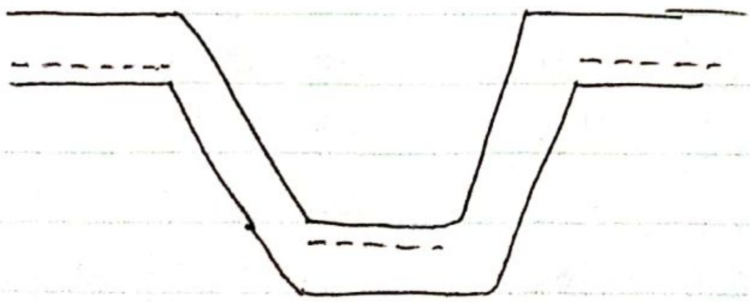
c. 

at eq.

On state.

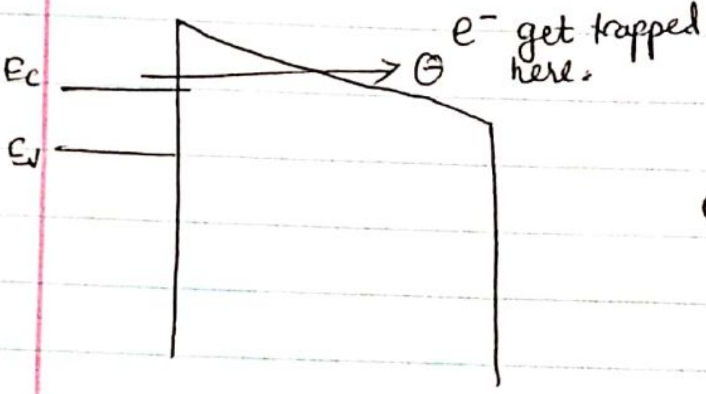
Saturation. 

off state

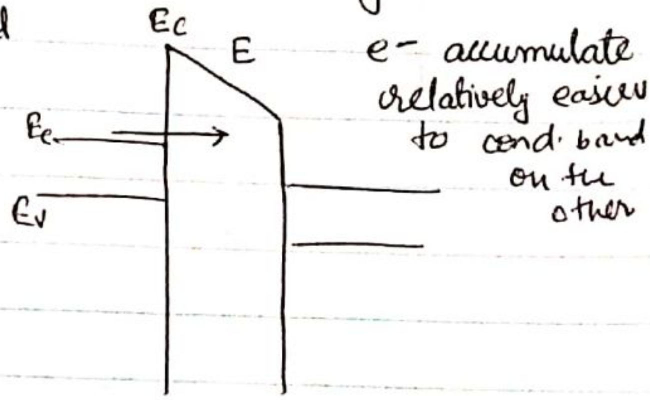


Q 4 dielectric breakdown.

Nordheim - Fowler.

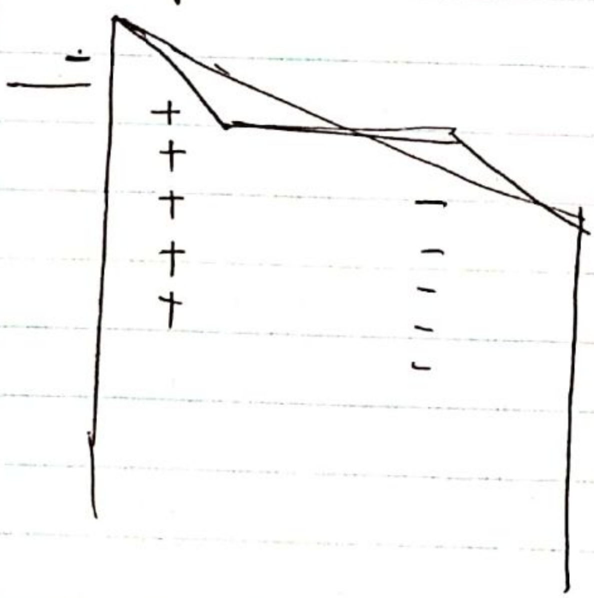


Tunnelling.



Most likely to happen is tunnelling (2) because devices are getting smaller & smaller & Oxide thickness is reducing.

Time dependent



Time dependent Dielectric Breakdown.

with high elec field e^- gain energy & due to impact ionisation cause EHP which end up getting trapped in the oxide regions. and alter the electric field.