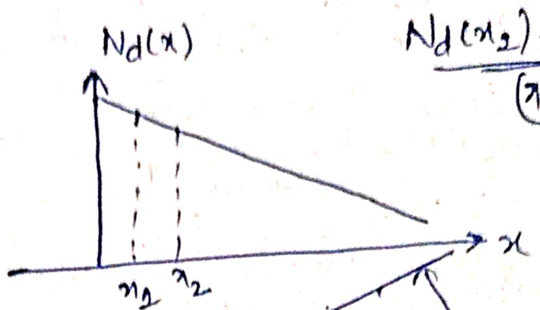
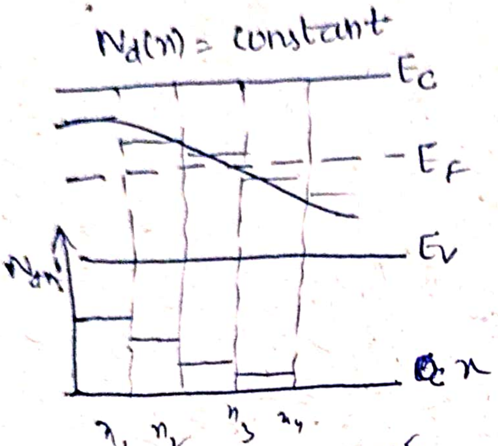
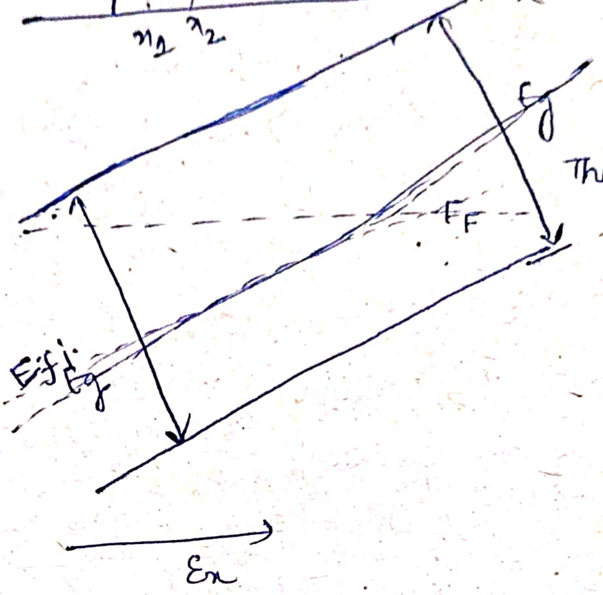
4th Feb, 2025

$$\frac{N_d(x_2) - N_d(x_2)}{(x_2 - x_1)}$$



$N_d(x)$ = constant





The fermi-level in a material always constant until we change its configuration mean. break it into small pieces or change it into something

doping concentration ఎంత ఎక్కువ ఉంటే EF and Ec మధ్య gap అంత తక్కువ ఉంటుంది.

n_0, p_0 depends on $e^{(E_F - E_i)}$ or $e^{-(E_F - E_{Fi})}$

* If there is conc. gradient there is diffusion of charges

diffusion current $\propto$ conc gradient.

If charge diffused there is current flow.

→ There current flow is not continuous.

conc gradient is more in n-p connection

diffusion current ని ఆపడానికి ఒక built-in potential ఉంటుంది.

* e^- moves from high conc to low conc

↓

pentavalent ఆర్ doping చేసినప్పుడు

+ve → free e^- → it diffuses

This is called uncovered atom (+ve charged atom)

once it diffused the neutrality of atom will be destroyed

atom gets +ve charge.

$$n(x) = n_i e^{(E_F - E_{Fi}(x))/kT}$$

$$\boxed{E_F - E_{Fi} = kT \cdot \ln\left(\frac{N_d(x)}{n_i}\right)}$$

$$-\frac{dE_{Fi}}{dx} = \frac{kT}{N_d(x)} \cdot \frac{dN_d(x)}{dx}$$

$$\boxed{\mathcal{E}_x = \frac{-kT}{q N_d(x)} \frac{d(N_d(x))}{dx}}$$

$$-\frac{dV}{dx} = \frac{1}{q} \frac{dE_{Fi}}{dx} = \mathcal{E}_x$$

$$\frac{1}{q}(E_F - E_{Fi}) = V$$

$$\boxed{n(x) \simeq N_d(x)}$$

$$n(x) \simeq N_d(x)$$

$$J_n = 0 = q N_d(x) \mu_n \mathcal{E}_x + q D_n \frac{dN_d(x)}{dx}$$

↓

current density contributed by electrons

$$\boxed{N_d(x) \mu_n \left(\frac{-kT}{q} \cdot \frac{1}{N_d(x)} \frac{dN_d(x)}{dx}\right) = q D_n \frac{dN_d(x)}{dx}}$$

$$\boxed{\frac{D_n}{\mu_n} = \frac{kT}{q}} = \frac{D_p}{\mu_p}$$

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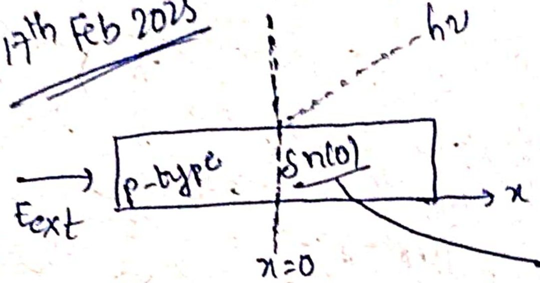
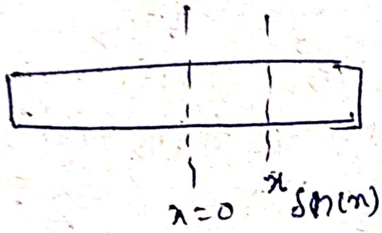


(excess e^--hole pairs)

excess carriers generated by optical illumination

Ambi-polar Transport phenomena

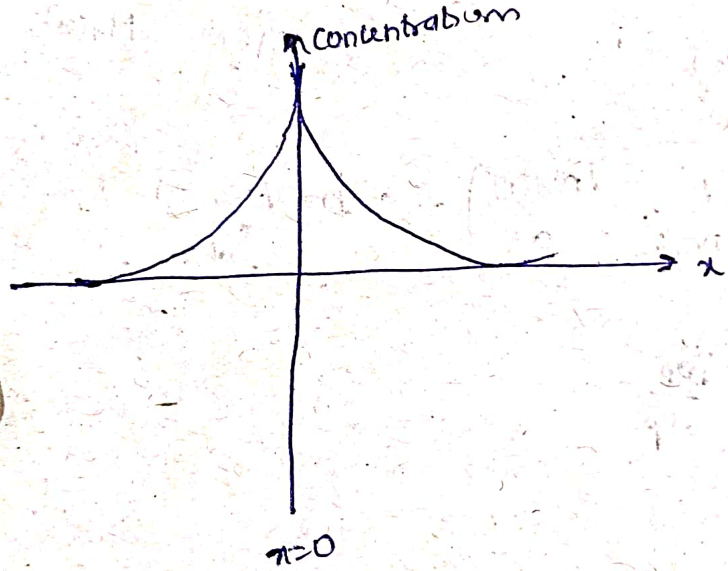
after it became maximum it will fall
Concentration will fall



$$\delta n(x) = \delta n(0)\, e^{-x/L_n} \quad \text{for } x \geq 0$$

$$\boxed{\begin{aligned} \delta n(x) &= \delta n(0)\, e^{-x/L_n} \quad \text{for } x \geq 0 \\ \delta n(x) &= \delta n(0)\, e^{x/L_n} \quad \text{for } x \leq 0 \end{aligned}}$$

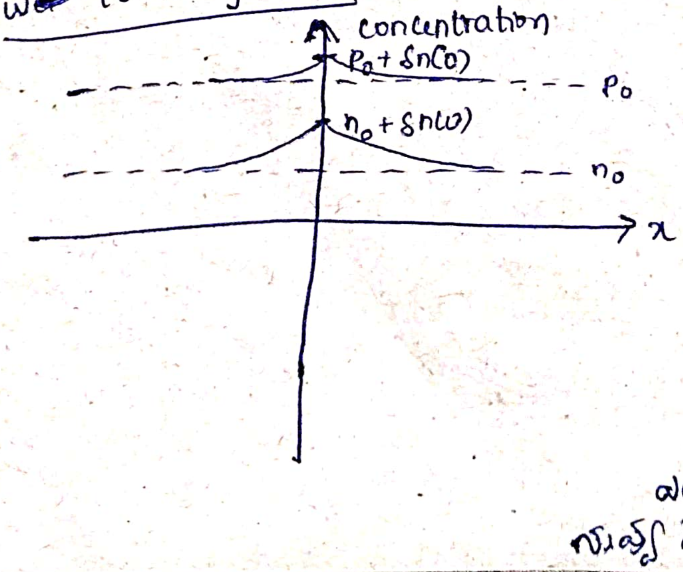
$L_n \rightarrow$ suffix not multiplication



low level injection → it has some significance

$p_0 \rightarrow$ hole conc

$n_0 \rightarrow e^-$ conc.



$\delta n(0) \ll p_0$

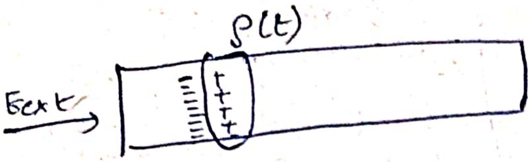
$n_0 \ll p_0$

ఇక్కడ n_0 కి $\delta n(0)$ add చేసినప్పుడు raise ఎక్కువ కనిపిస్తుంది compared when added to p_0

ఎందుకంటే $n_0 \ll p_0$ $\delta n(0) \ll p_0$

ఎప్పుడూ పెద్ద quantity కి చిన్న value add చేస్తే పెద్ద తేడా ఉండదు

$\rho(t)$



$\rho = qN_a$

$\boxed{\rho = qN_a}$

electric field apply చేసినప్పుడు

Internal గా polarization ఉత్పత్తి అవుతుంది

electric field తీసేసాక ఆ polarized/accumulated charge will be evenly distributed ఆ fall out ఎలా జరుగుతుంది మనం కనుక్కోవాలి.

$$\nabla \cdot \vec{E} = \rho/\epsilon$$

$$\vec{J} = \sigma E$$

$$\nabla \cdot J = -\frac{\partial \rho}{\partial t}$$

$$\nabla \cdot J = \sigma\left(\rho/\epsilon\right)$$

$$\frac{\partial \rho}{\partial t} + \frac{\sigma}{\epsilon}\rho(t) = 0$$

$$\boxed{\rho(t) = \rho(0)e^{-t/\tau_d}}$$

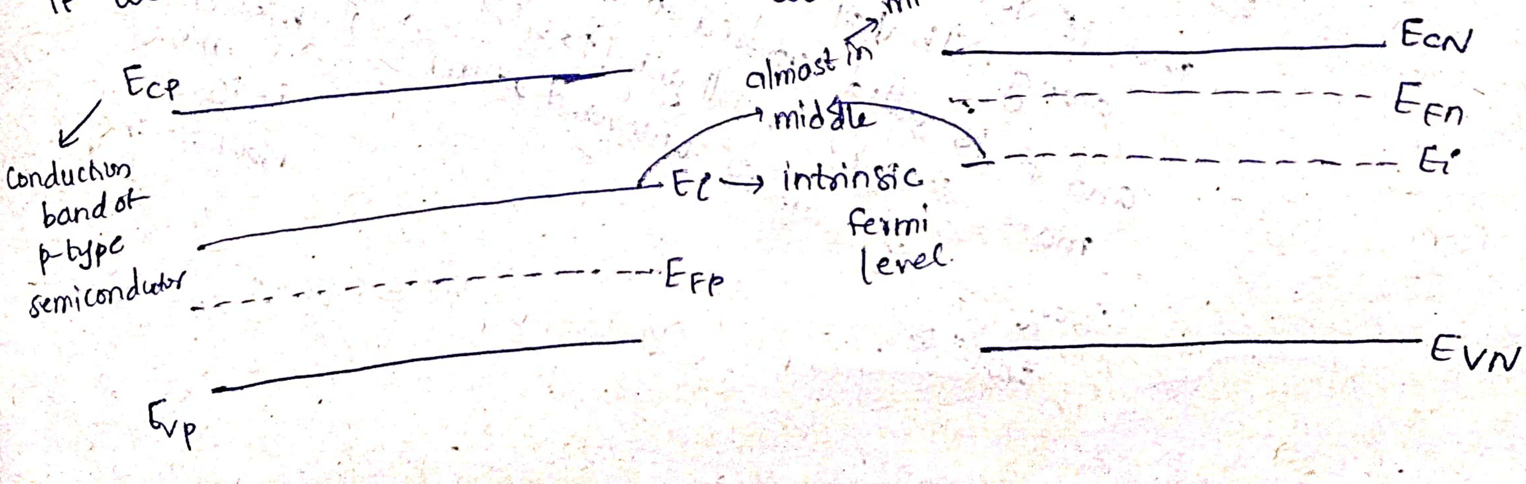
$$\sigma = q(\mu_p + \mu_N)$$

$$\boxed{\tau_d = \sigma/\epsilon} \rightarrow \text{identii (??) chadu}$$

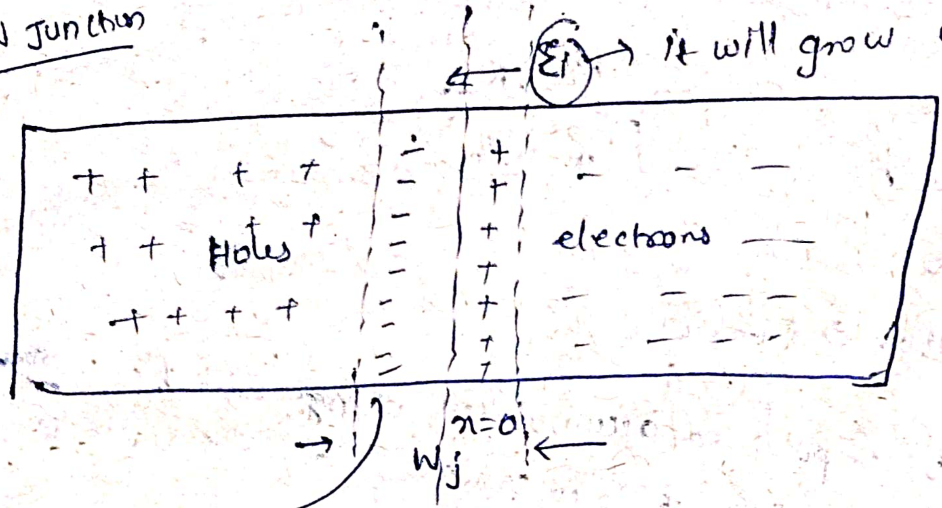
↓ dielectric relaxation time

---

if we have 2-such Junction (పక్క పక్కన) ఉంటే middle లో ఉంటది నేను తప్పు కాదు Time లేదు సరి చేయలేను



P-N Junction



it will grow until it is sufficient to stop the current

Uncovered atoms

diffusion happens due to carrier concentration variation

⇓

it will create current

⇓

This is current is stopped by built in potential.

ఇక్కడ actually holes diffuse అవుతాయి వెళ్ళిపోవడం shortage of holes creates negative charge there

similarly other side as e^-s more creates shortage of e^-s creates positive charge

ఇప్పుడు right side ఉన్న atoms (dopant) n-type ex- pentavalent ఉంటాయి

outer cell $5e^-$ ఉంటాయి $4e^-$ will be covalent bond and $1e^-$ is free

along with that e^- that atom is neutral and it is called covered atom e^- more అయితే it will get (positive charge) due to excess proton → This can't be moved it is Bound charge

ఇప్పుడు ఈ atom ని uncovered atom అంటారు

$w_j \rightarrow$ Junction width

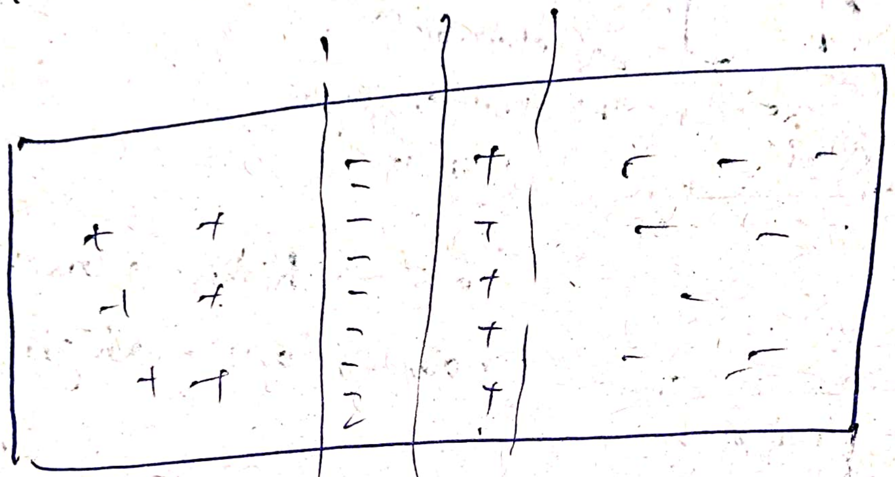
The charge at Junction and p-type and n-type are completely different

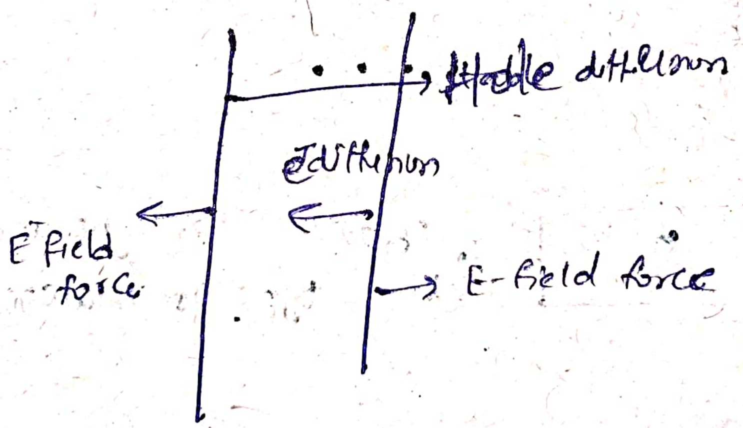
⇓ These are fixed uncovered atoms

⇓ These are free to move

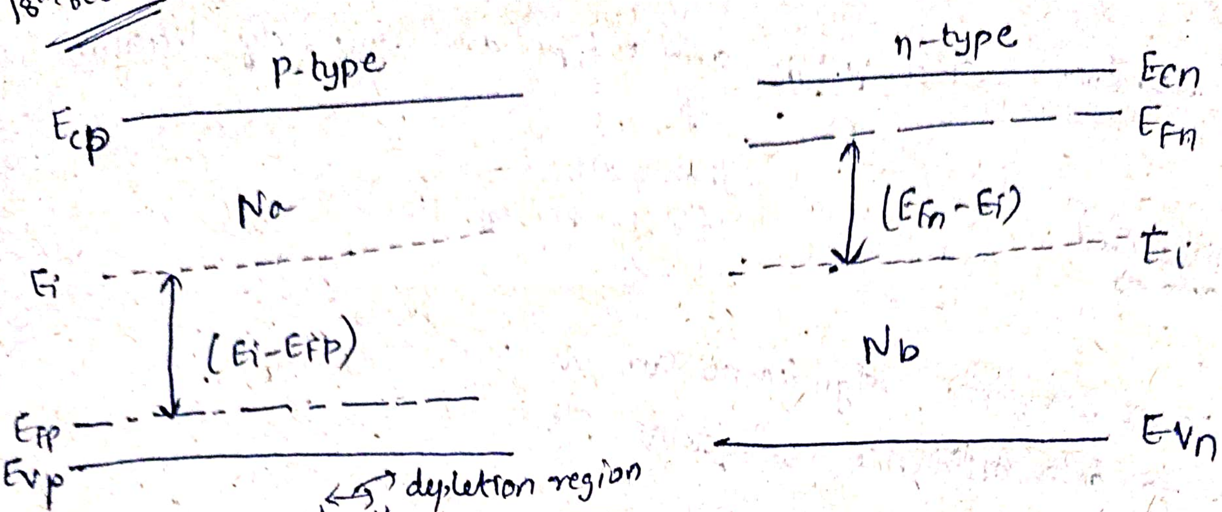
0.6–0.7V వచ్చినప్పుడు significant current increase అవుతుంది

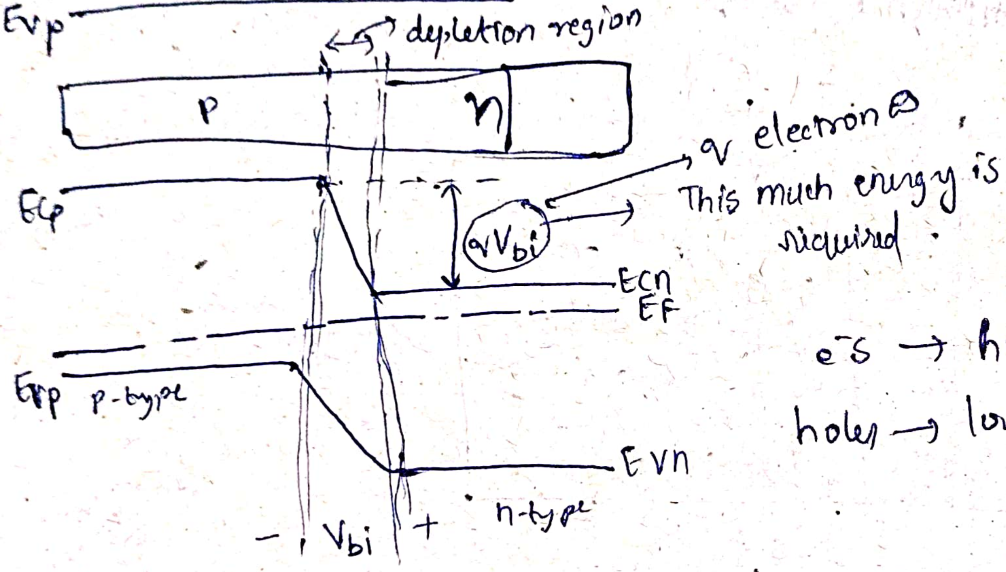
0.7V–1.7V → ఏమీ difference కనపడదు ఇక్కడ





18th Feb 2016

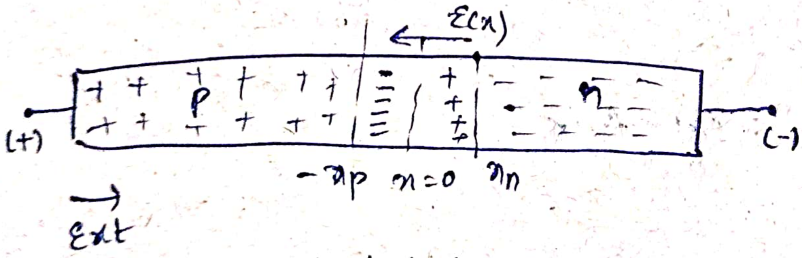




$e^-s \rightarrow$ higher $\rightarrow$ lower easily

holes $\rightarrow$ lower $\rightarrow$ higher easily

final p-n Junction will look like this



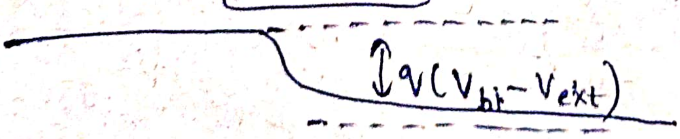
ఇరువైపుల p-type and n-type same type of material వాడుతున్నాం

$W_j = |x_p| + |x_n|$

$\downarrow$

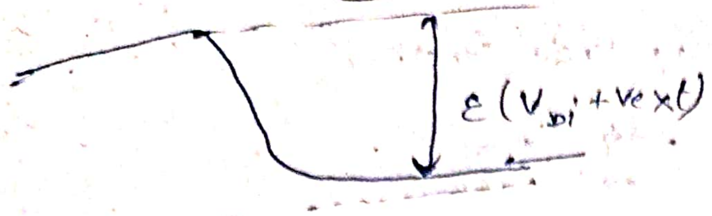
Junction width

$\boxed{\text{Forward bias}}$



Reverse bias

Reverse bias



eauilibrium లో లేకపోతే fermi level change అవుతుంది.

doping will not change band gap only changes fermi level

* High $-\bar{e}$ mobility transistors ⟶ made using Heterogenic Junction.

E,4 derivations
Numerical problems
remember formulas

→ derivations ⟵

V_{bi}

Junction width

E_{FP} and E_{Fn} must be aligned

N_a, N_b are doping concentrations

$$qV_{bi} = (E_i - E_{FP}) + (E_{Fn} - E_i)$$

$$N_a \approx P_o = n_i e^{(E_i - E_{FP})/KT}$$

$P_o = n_i + N_a$

$N_a >> n_i$

$P_o \approx N_a$

$$(E_i - E_{FP}) = KT \ln\left(\frac{N_a}{n_i}\right)$$

$$(E_{Fn} - E_i) = KT \ln\left(\frac{N_b}{n_i}\right)$$

$$qV_{bi} = KT\ln\left[\frac{N_a}{n_i}\right] + KT\ln\left(\frac{N_b}{n_i}\right)$$

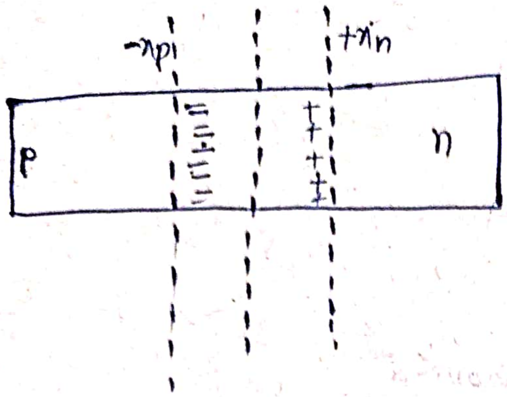
$$\boxed{V_{bi} = \frac{KT}{q} \ln\left(\frac{N_a \times N_b}{n_i^2}\right)}$$

$$V_{bi} = \frac{kT}{q} \ln\left(\frac{N_a \times N_b}{n_i^2}\right)$$

$\phi(x) \rightarrow$ potential function

$$-\frac{d\phi}{dx} = \mathcal{E}(x)$$

$$\nabla^2 \phi = -\rho/\epsilon$$



$$\rho(x) = -qN_a \quad \text{for } -x_p \le x \le 0$$

$$\rho(x) = +qN_b \quad \text{for } 0 \le x \le x_n$$

solve for other half

$$\frac{d^2\phi(x)}{dx^2} = -\frac{\rho(x)}{\epsilon} = \frac{qN_a}{\epsilon}$$

$$\frac{d}{dx}\left(-\mathcal{E}(x)\right) = \frac{qN_a}{\epsilon}$$

$$d\mathcal{E}(x) = -\frac{qN_a}{\epsilon}\, dx$$

$$\mathcal{E}(x) = \frac{-qN_a}{\epsilon} x + C_1$$

$$0 = \frac{-qN_a(-x_p)}{\epsilon} + C_1$$

$$C_1 = -\frac{qN_a x_p}{\epsilon}$$

$$\boxed{\mathcal{E}(x) = -\frac{qN_a}{\epsilon}(x + x_p)} \quad \text{for } -x_p \le x \le 0$$