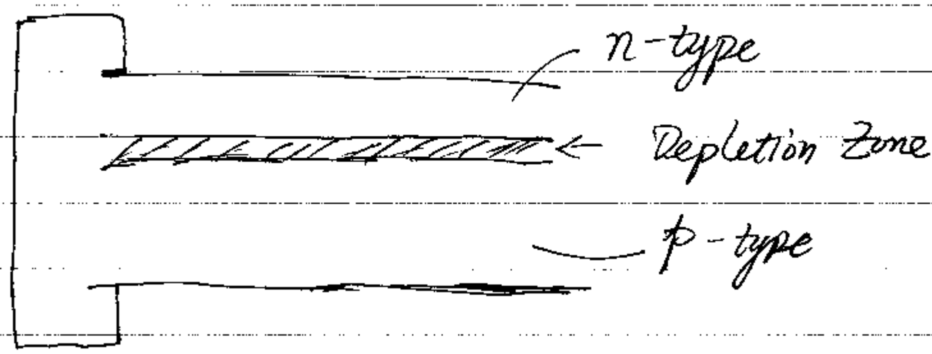
MAE 119 W2017
Prof. G.R.Tynan
Quiz 6

Closed Book Closed Notes

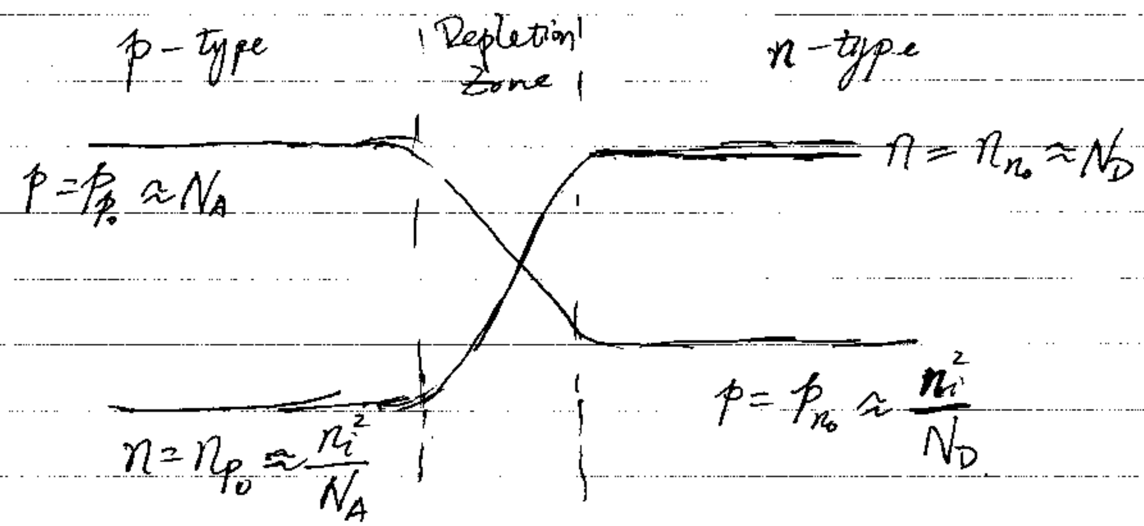
1. Draw a diagram of a solar photovoltaic (PV) cell, labeling the n-type, p-type and junction regions. 5 points.
2. Sketch a spatial profile of the mobile electron and mobile hole density across the device, indicating where they are large, where they are small, and the region where there is a strong spatial gradient in their density. 5 points.
3. Where does a natural electric field develop in this device, and what regions are quasineutral and thus have zero electric field? 5 points.
4. Now suppose this PV cell is connected to an external circuit with a forward voltage applied that acts to partially or fully counter-act the potential drop associated with the electric field discussed in part 2 above. How does the electron and hole density across the device change when this external voltage is applied? 5 points.
5. By definition there is no electric field in the quasineutral region. How then do the mobile charges move across these regions? If the PV cell has a planar geometry, what is the functional form of the minority carrier density in the quasineutral regions? 5 points.
6. If the mobile carrier lifetime was increased by an improved manufacturing cell process, and nothing else changed in the PV cell, what would happen qualitatively to the mobile charge distribution across the quasineutral regions? 5 points.
7. Sketch the current-voltage characteristic of the PV cell for the case of zero illumination, and the case of illumination with a solar spectrum. Label the short circuit current, I_{sc}, open circuit voltage, V_{OC}, and point of maximum power production. 5 points.
8. Suppose your solar cell has I_{sc}= 20 milli-Amps/cm^2 and V_{OC}=1 V, and has a form factor, FF = 0.5, and is illuminated with an solar flux of 1000 W/m^2 that is perpendicular to the surface. How much electrical power will a 1 m^2 panel produce? 5 points.

Quiz 6. Mar 15, 2017

1.

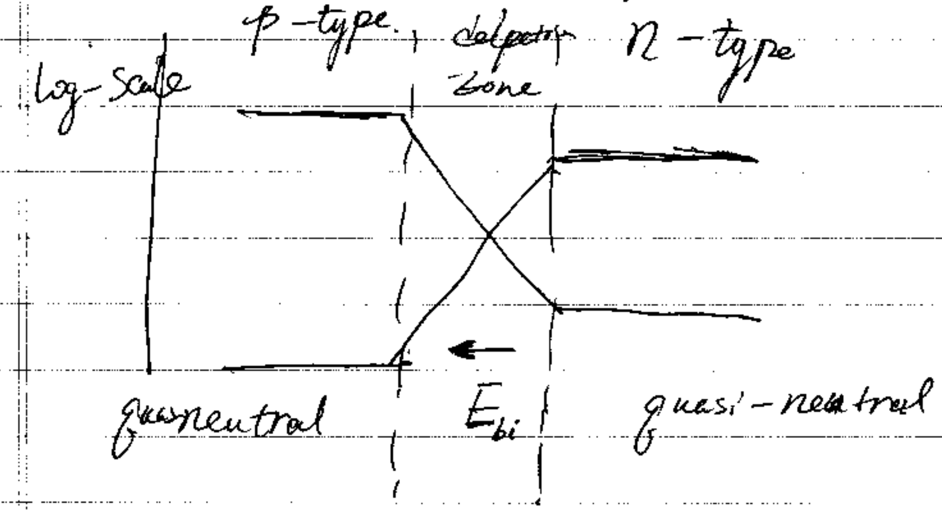


2.

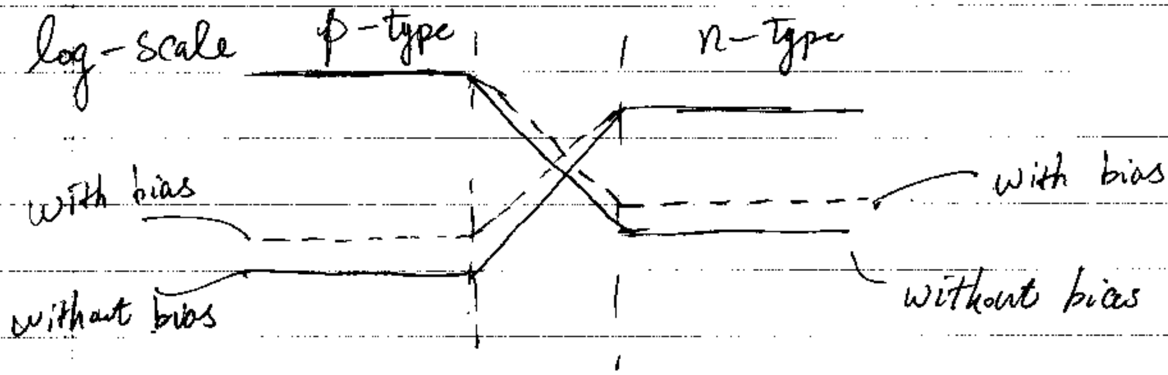


3.

The electric field develops at the p-n interface.



4. Minority Density at edge of quasineutral region increases exponentially with forward bias.



5. Current flow is purely diffusive.

p-side: $J_n = qD_n \frac{dn}{dx}$

n-side: $J_p = -qD_p \frac{dp}{dx}$

Using Continuity Eqn. we get.

$$\frac{1}{q}\frac{dJ_n}{dx} = \frac{\Delta n}{\tau_n}, \quad \text{where } \Delta n = n(x) - n_{p_0}$$

and $$-\frac{1}{q}\frac{dJ_p}{dx} = \frac{\Delta p}{\tau_p}, \quad \text{where } \Delta p = p(x) - p_{n0}$$

Therefore.

$$\frac{d^2\Delta n}{dx^2} = \frac{\Delta n}{L_n^2}, \quad L_n^2 = D_n\tau_n$$

$$\frac{d^2\Delta p}{dx^2} = \frac{\Delta p}{L_p^2}, \quad L_p^2 = D_p\tau_p.$$

5. cont'd.

The general solutions have the form of

$$Ae^{+x/L} + Be^{-x/L}$$

Boundary Conditions :

① At depletion zone edge.

$$n(0) = n_{p_0} \exp\left(\frac{qV_a}{k_BT}\right)$$

$$p(0) = p_{n_0} \exp\left(\frac{qV_a}{k_BT}\right).$$

② ∵ At $x \to \infty$ concentration should be finite.

∴ $A \to 0$.

Thus $p(x) = p_{n_0} + p_{n_0}\left[\exp\left(\frac{qV_a}{k_BT}\right) - 1\right] e^{-x/L_p}$

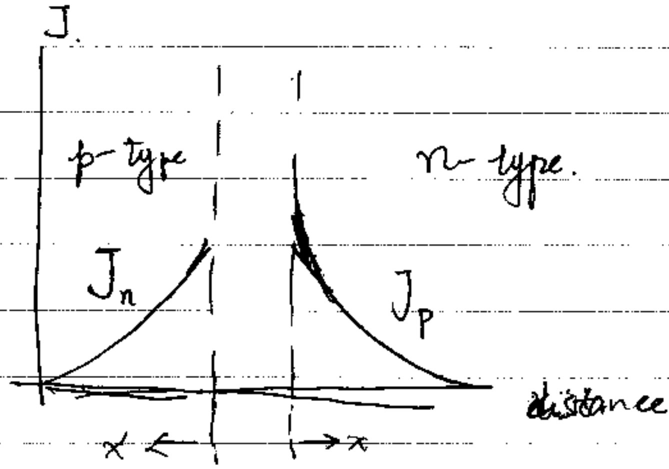
$$n(x) = n_{p_0} + n_{p_0}\left[\exp\left(\frac{qV_a}{k_BT}\right) - 1\right] e^{-x/L_n}.$$

The current will be.

$$J_n = -q\frac{D_n n_{p_0}}{L_n}\left[\exp\left(\frac{qV_a}{k_BT}\right) - 1\right] e^{-x/L_n}$$

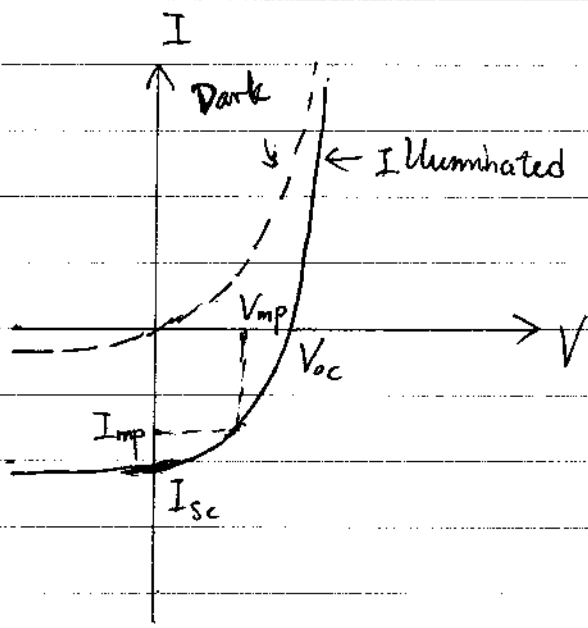
$$J_p = q\frac{D_p p_{n_0}}{L_p}\left[\exp\left(\frac{qV_a}{k_BT}\right) - 1\right] e^{-x/L_p}$$

5. cont'd.



6. If carrier lifetime is increased, $L = \sqrt{D\tau}$ also increases leading to slower decay of the concentration distribution in quasi-neutral regions.

7.



8. $P = FF \cdot I_{sc} \cdot V_{oc} = I_{mp} V_{mp}$, $\eta = 10\%$
$= 100 \, W/m^2$