UCSD MAE 119 Winter 2018
Prof. G.R. Tynan

Quiz 6: Solar PV

Closed book, closed notes. Calculators permitted (but not needed)

1. *Basics of ideal diode model of solar cell* (20 points)
    a. Sketch a p-n diode without illumination and label the p-type, n-type, and junction regions (5 points).
    b. Show the majority carrier densities p_{p0} and n_{n0}, as well as the minority carrier densities, p_{n0} and n_{p0} which occur in the absence of a forward bias, i.e. with V_a=0 (5 points).
    c. When a forward bias, V_a>0, is applied to such a device, the minority carrier densities change substantially. In this case sketch what the distribution of the holes and electrons looks like and indicate the diffusion lengths L_e and L_h of the minority carrier distributions (10 points).

2. *Current-voltage response of a solar cell* (25 points): When the p-n diode is illuminated with a light source that is capable of producing e-h pairs, current-voltage response of such a device is given as

$$I(V) = I_0\left(\exp\left(qV / kT\right) - 1\right) - I_L$$

where

$$I_L = I_{sc} = qAG(L_e + W + L_h) \qquad .$$

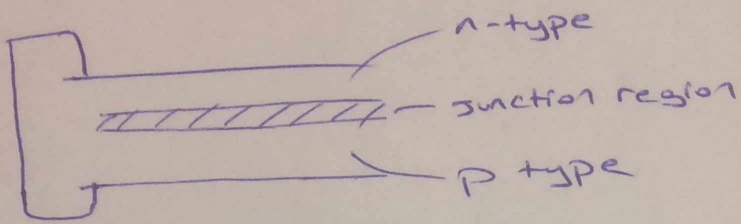
    a. Draw *I(V)* for the case of no illumination (*G=0*) (5 points).
    b. Draw (IV) for finite illumination (*G>0*) (5 points).
    c. Label the short-circuit current I_{sc} and the open-circuit voltage V_{oc} *(5 points),*
    d. Label the location of maximum power production (I_{mp},V_{mp}) (5 points).
    e. Label the power-producing quadrant when *G>0 (5 points)*.

3. 15 points. Suppose the minority charge carrier lifetime in a PV cell could somehow be increased by 4x.
    a. What will be the change in the efficiency of the PV cell? [Hint: remember the diffusion length concept that connects to the diffusion coefficient and carrier lifetime, and that the units of the diffusion coefficient are L^2/T.] (5 points)
    b. Referring to the result of problem 2 above, how would the I(V) response of the cell change? (5 points)
    c. Explain in a few words how the minority carrier density in the p and n type regions would change if this occurred (5 points)

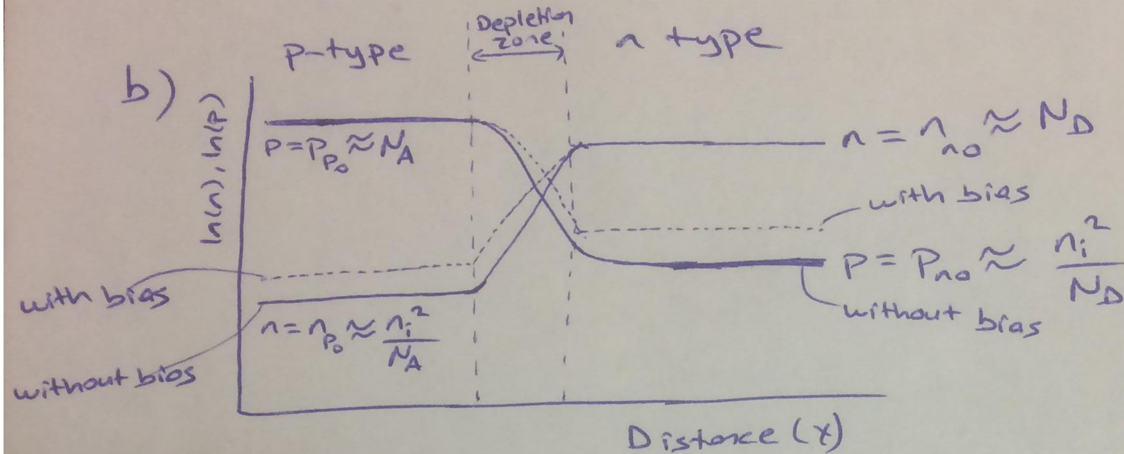
QUIZ 6

1)

a)



b)



c) Minority carrier densities at edge of quasineutral region increases exponentially with forward bias. Not: Bias effect is shown on the above graph.

Current transport occurs via diffusion in the quasineutral region where $E=0$.

Not: P subscript corresponds h, n subscript corresponds e in the below solution.

P side: $J_n = q D_n \frac{dn}{dx}$

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

Using continuity equation (hole conservation law) we get

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

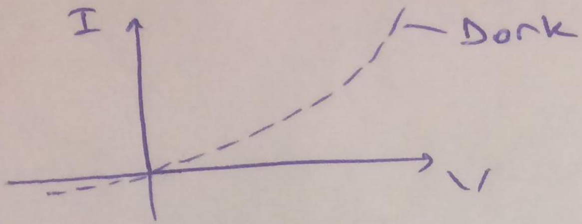
$$-\frac{1}{q}\frac{dJ_p}{dx} = \frac{\Delta p}{\tau_p} \qquad \text{where } \Delta p = p(x) - p_{n_o}$$

Therefore

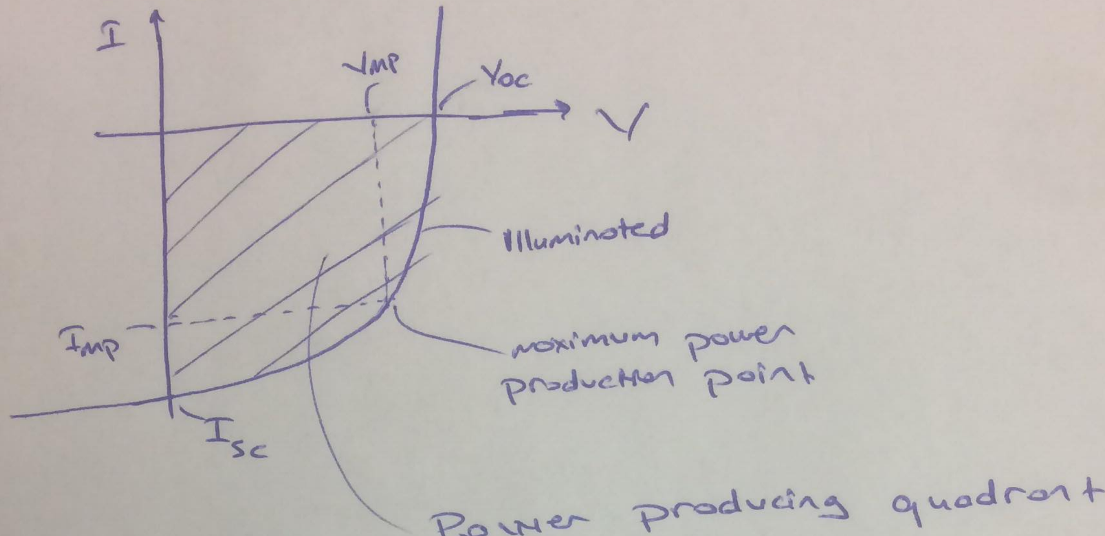
$$\frac{d^2 \Delta n}{dx^2} = \frac{\Delta n}{L_n^2} \qquad L_n^2 = D_n \tau_n \qquad L_n = \sqrt{D_n \tau_n}$$

$$\frac{d^2 \Delta p}{dx^2} = \frac{\Delta p}{L_p^2} \qquad L_p^2 = D_p \tau_p \qquad L_p = \sqrt{D_p \tau_p}$$

2) a)



b)
c)
d)
e)



3) a) $L = \sqrt{D \tau}$

$$\eta = \frac{FF \, V_{oc} \, j_{sc}}{I_0}$$

$$j_{sc} \propto L_{e,h} \propto \tau_{e,h}^{1/2}$$

$$j'_{sc} = 2 \, j_{sc}$$

Effrcrency is doubled.

b) V_{oc} voltage doesn't change as it is not related to defect density (charge carrier lifetime)
I_{sc} is doubled. Area under I-V curve (power producing quadrant) is doubled. as effrcrency is doubled.

c) Minority carrier density in the p and n type region would increase as if carrier lifetime is increased, electron and hole diffusion length ($L_{e,h} = \sqrt{D_{e,h} \tau_{e,h}}$) increases and this leads slower decay of the concentration distribution in p and n type regions.