Ghousia College of Engineering

Department of Electronics and Communication

EC 56: Solid State Devices and Technology.

Hints for Assignment for Internal Exam #2.

1. (a), (b) & (c) can be found in the lecture notes - 11 (JFET)

(d) Use the equation (i) $V_0 = \frac{KT}{q} \ln\left(\frac{N_A N_D}{n_i^2}\right)$

(ii) use the expression for V_p, Refer to the lecture notes 11, Eqn. (4)

2. (a), (b), (c), Refer to the lecture notes - 12.

(d) Refer to the leture notes - 11, Ohmic region.

3. Refer to Example 9.2, Page 278, Kanaan Kano "semiconductor devices" Do this problem in the same way as this example.

4. Refer to the lecture notes - 10, (a, b, c, d, e, & f)

(g) Use Eqns (42) & (37) Note that there is a correction in Eqn (37) it is $\beta_0 = g_m r_\pi$ (not $g_m v_\pi$)

5. Refer to the class notes (This notes has not been uploaded yet, i.e as on Date: 8th Nov 06).

6. (a) Refer to lecture notes - 3. Eqn (7) you have to derive.

(b) Refer to Problem in Lecture notes (4), it is similar to this problem.

7. (a), (b) can be found in lecture notes - 9.

(c) Given $V_0 = 0.2V$

From the lecture notes - 9, Eqn. (5) we have

$$V_j = \frac{q}{2\epsilon}\left(\frac{N_A N_D}{N_A + N_D}\right) W^2$$

where V_j is the junction voltage $= V_0 - V_D$

$V_D = V_F$ for forward bias voltage 'V_F'

$= -V_R$ for Reverse bias voltage 'V_R'.

$$\therefore V_j = V_0 - V_D = \frac{q}{2\epsilon}\left(\frac{N_A N_D}{N_A + N_D}\right) W^2 \quad \text{—(1)}$$

Given $N_D \gg N_A$ & hence $V_j = \frac{q}{2\epsilon}\left(N_A \right) W^2$ [Prove this equation from equation (1)]

$$\therefore V_j = \frac{q N_A}{2\epsilon} W^2 = V_0 - V_D.$$

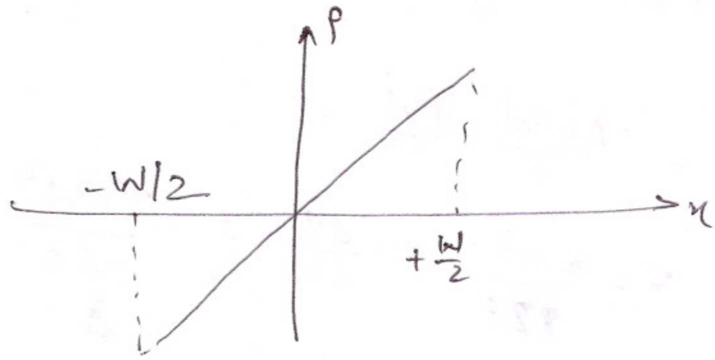
By this formula you can do, (i), (ii) & (iii)

In (iv) there is a small correction instead of (a), & (b) it should be (i) & (ii)

Thus use the values obtained for depletion region 'W' in (i) & (ii) & using the formula $C_T = \frac{\epsilon A}{W}$ calculated

Space-charge capacitance.

Given $\rho = ax$ = charge density.



From the Poission equation, we have $\frac{d^2V}{dx^2} = \frac{-\rho}{\epsilon}$

$\therefore$ integrating both sides w.r.t 'x' we get

where 'K_1' is a integration const.

$$\frac{dV}{dx} = \frac{-ax^2}{2\epsilon} + K_1$$

at $x = -\frac{W}{2}$ $\quad \frac{dV}{dx} = 0. \Rightarrow K_1 = \frac{aW^2}{8\epsilon}$

$$\therefore \frac{dV}{dx} = \frac{-ax^2}{2\epsilon} + \frac{aW^2}{8\epsilon}$$

Again integrating both sides w.r.t 'x' we get

$$\Rightarrow V = \frac{-ax^3}{6\epsilon} + \frac{aW^2}{8\epsilon}x + C_2$$

at $x = -\frac{W}{2}$ $\quad V = 0$

$$\Rightarrow C_2 = \frac{-aW^3}{48\epsilon} + \frac{aW^3}{16\epsilon} = \frac{aW^3}{24\epsilon}.$$

$\therefore$ $\cancel{V = \frac{-ax^3}{48\epsilon} + \frac{aW^3}{16\epsilon}}$ $\quad V = \frac{-ax^3}{6\epsilon} + \frac{aW^2}{8\epsilon}x + \frac{aW^3}{24\epsilon}$

at $x = \frac{W}{2}$ $\quad V = V_j = \frac{-aW^3}{48\epsilon} + \frac{aW^3}{16\epsilon} + \frac{aW^3}{24\epsilon} = \frac{aW^3}{12\epsilon}.$

$$\therefore \boxed{V_j = \frac{aW^3}{12\epsilon}}$$

Hence proved.

(b) $Q = \int_0^{W/2} A\rho\, dx = \int_0^{W/2} A\,(ax)\, dx = \frac{AaW^2}{8}.$

& $C_T = \frac{dQ}{dV} = \frac{AaW}{4} \frac{dW}{dV}$

But from (a) $V = \frac{aW^3}{\cancel{12}\,24\epsilon} \Rightarrow \frac{dV}{dW} = \frac{\cancel{3}aW^2}{\cancel{24}\,8\,\epsilon} = \frac{aW^2}{\cancel{4}\,8\epsilon}$

$\Rightarrow \frac{dW}{dV} = \frac{\cancel{4}\,8\epsilon}{aW^2}$

$\therefore C_T = \frac{A\cancel{a}\cancel{W}}{\cancel{4}} \times \frac{\cancel{4}\,2\epsilon}{\cancel{a}W^{\cancel{2}}} = \frac{A\epsilon}{W}.$

$\boxed{C_T = \frac{\epsilon A}{W}}$ proved.

9(a) Refer to Lecture Notes -10.

(b) Argue on $r_{DS(ON)}$, Refer to Lecture Notes -11, Eq (8).

(c) Refer to Page - 314 ~~Kanaan~~ Kano "Semiconductor Devices".

(d) If $N_A << N_D$ then

$V_j = \frac{q}{2\epsilon} N_A w^2.$

& σ_p = conductivity of holes = $q N_A \mu_p$.

$\Rightarrow qN_A = \frac{\sigma_p}{\mu_p}.$

$\Rightarrow V_j = \frac{\sigma_p}{\mu_p} \cdot \frac{1}{2\epsilon} \cdot w^2$

$\Rightarrow W^2 = \frac{2\epsilon \mu_p V_j}{\sigma_p}$

$\Rightarrow W = \left(\frac{2\epsilon \mu_p V_j}{\sigma_p} \right)^{1/2}$

(10) (a) For silicon p-n junction with $N_A << N_D$, & $\epsilon_r = 11.8$,

the depletion capacitance ~~per unit~~ in pF per square centimeter

is given by

$$C_T = 2.9 \times 10^{-4} \left(\frac{N_A}{V_j}\right)^{1/2}.$$

given $D = 40 \times 10^{-6}\ m \Rightarrow A = \frac{\pi D^2}{4} = ?$

$\rho = 3.5\ \Omega\text{-cm}$ $\qquad \rho = \frac{1}{q \mu_p N_A}$

$\mu_p = 500\ cm^2/V\text{-}s.$ & find N_A.

$\therefore$ for $V_j = V_0 - V_D = V_0 - (-V_R)$

$= V_0 + V_R$

Hence we know all the parameters in expression for C_T

Find $C_T = ?$

(b) From lecture Note-9, Eqn.(17) we have $C_D = \frac{\tau_p I}{\eta V_T}$.

$\eta = 2$ for silicon, $I = 1\ mA$,

$C_D = 1\mu F$, but $L_p^2 = D_p \tau_p \Rightarrow \tau_p = \frac{L_p^2}{D_p}$.

$$\therefore C_D = \frac{L_p^2}{D_p} \cdot \frac{I}{\eta V_T} \qquad V_T = \frac{T}{11600}.$$

$$\Rightarrow L_p^2 = \frac{C_D D_p}{I} \cdot \eta V_T.$$

Find $L_p = ?$

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