$V_p = \frac{4.05 \times 10}{1.44 \times 10^{6}} = 2.8125$ # (+1)

(+10)

2. Calculate the built-in voltage of a PN junction in which the p and n regions are doped equally with 5×10^{16} atoms/cm^3. Assume $n_i = 1.5 \times 10^{10}$/cm^3.

(a) (5%) With the terminals left open, what is the width of the depletion region?

$N_A = N_D = 5 \times 10^{16}$ atoms/cm^3 , $n_i = 1.5 \times 10^{10}$/cm^3

① $V_o = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$ (+2) $= 25.9 \ln\left(\frac{5\times10^{16} \times 5\times10^{16}}{(1.5\times10^{10})^2}\right) = 718\,mV$ (+1)

② $\varepsilon_s = (11.7 \times 8.854 \times 10^{-14}\ F/cm)$ (+2) $= 1.036 \times 10^{-12}$ (+1)

③ $W = \sqrt{\frac{2\varepsilon_s}{q}\left(\frac{1}{N_A}+\frac{1}{N_D}\right)V_o} = \sqrt{\frac{2\times1.036\times10^{-12}}{1.6\times10^{-19}}} = 0.2\ \mu m$ (+1) #

(b) (10%) and how far does it extend into the p and n regions?

(+3) (+2)

$x_n = W \frac{N_A}{N_A+N_D} = 0.1\ \mu m$ #

(+3) (+2)

$x_p = W \frac{N_D}{N_A+N_D} = 0.1\ \mu m$ #

(c) (5%) If the cross-sectional area of the junction is 20 μm^2, find the magnitude of the charge stored on either side of the junction.

$A = 20\ \mu m^2 = 20 \times 10^{-8}\ cm^2$

(+3)

$Q_j = Aq\left(\frac{N_A N_D}{N_A+N_D}\right)W = 20\times10^{-8} \times 1.6\times10^{-19}\left(\frac{5\times10^{16}}{2}\right) \times 0.2\times10^{-4}$

$= 1.6 \times 10^{-14}\ C$ (+2) #

3. (20%) Consider an n-channel MOSFET with $t_{ox} = 6$ nm, μ_n =460 cm^2/V•s, $V_t = 0.5$ V, and $W/L = 10$. Find the drain current in the following cases:

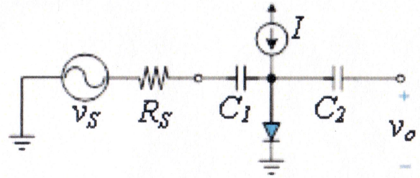
(a) v_{GS} =2.5V and v_{DS} =1.0 V

$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{3.45\times10^{-11}}{6\times10^{-9}}$ (+1), $V_{ov} = V_{GS} - V_t = 2\,V$ (+1)

$k_n = \mu_n C_{ox} \frac{W}{L} = 2.645\ mA/V^2$ (+1)

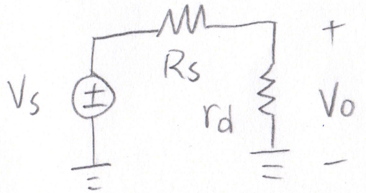
(b) v_{GS} =2.0V and v_{DS} =1.5 V

5. (20%) A signal attenuator as shown in below with the attenuation factor controlled by the value of the dc current I, and v_S is a sinusoidal signal. Capacitors C_1 and C_2 are very large; their function is to couple the signal to and from the diode but block the dc current from flowing into the signal source or the load (not shown in this drawing).



(a) Use the diode small-signal model to show that the signal component of the output voltage is

$$v_o = v_s \frac{V_T}{V_T + IR_s}$$



(+5)

(+2) $r_d = \frac{V_T}{I}$

(+3) $V_o = V_s \times \frac{r_d}{r_d + R_s} = V_s \frac{V_T/I}{V_T/I + R_s}$

$= V_s \frac{V_T}{V_T + IR_s}$

(b) If v_S = 10 mV, find v_o for I = 1 mA, 0.1 mA, and 1 μA. Let R = $1\ k\Omega$. At what value of I does v_o become one-half of v_S?

(+2) $V_o = \frac{V_T}{\ldots} = 10 \times \frac{25}{\ldots}$

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