EEE 207

# SOLUTIONS TO PROBLEM SHEET 4

Q1) $V_0 = \frac{kT}{e} \ln\left(\frac{p_p}{p_n}\right) = \frac{kT}{e} \ln\left(\frac{n_n}{n_p}\right)$

$\sigma_n = n_n e \mu_e \Rightarrow n_n = \frac{\sigma_n}{e\mu_e}$

$\sigma_p = p_p e \mu_h \Rightarrow p_p = \frac{\sigma_p}{e\mu_h}$

$\therefore n_p = \frac{n_i^2}{p_p} = \frac{n_i^2 e \mu_h}{\sigma_p}$

$$V_0 = \frac{kT}{e} \ln\left(\frac{n_n}{n_p}\right) = \frac{kT}{e} \ln \frac{\sigma_n \sigma_p}{e\mu_e n_i^2 e \mu_h} = \frac{kT}{e} \ln \frac{\sigma_n \sigma_p}{e^2 n_i^2 \mu_e \mu_h}$$

$$= \frac{(1.38 \times 10^{-23})(300)}{1.6 \times 10^{-19}} \ln \frac{(10^4)(10^2)}{e^2 (2.5 \times 10^{19})^2 (0.36)(0.17)}$$

$$= \underline{0.358 \text{ V}} \quad \#$$

Q2) Transconductance, $g_m = \frac{\mu_e C_g V_{ds}}{\ell^2}$ ; and $C_g = \frac{\varepsilon A}{d}$

$$\therefore g_m = \frac{\mu_e \varepsilon_0 \varepsilon_r V_{ds} A}{d \ell^2}$$

$$= \frac{(0.02)(8.854 \times 10^{-12})(3.7)(10)(0.84 \times 10^{-3})(5 \times 10^{-6})}{(5 \times 10^{-6})^2 (150 \times 10^{-9})}$$

$$= \underline{7.34 \times 10^{-3} \text{ S}} \quad \#$$

Q3)

$$I_d = \frac{\mu_e C_g}{\ell^2}\left(V_g - V_T - \frac{V_d}{2}\right)V_d \quad ; \text{ and since } \quad V_d \ll V_g, \quad V_d \ll V_T$$

$$\Rightarrow I_d \approx \frac{\mu_e C_g}{\ell^2}(V_g - V_T)V_d$$

If $V_g$ is fixed, we have $\frac{V_d}{I_d} = \frac{\ell^2}{\mu_e C_g (V_g - V_T)} = R$

Rearranging; $V_g = \frac{\ell^2}{\mu_e C_g R} + V_T$

$$= \frac{(5\times10^{-6})^2}{(0.02)(1\times10^{-12})(2\times10^3)} + 3$$

$$= \underline{3.625\text{ V}} \quad \#.$$

Possible disadvantages depend on precise applications, but R depends on $V_g$; also depends on MOST characteristics which may be difficult to control; noise on $V_g$ is also transferred to rest of the circuit; only a linear resistor for low $V_d$; more complicated than a simple R.

Q4) $I_d = \frac{\mu_e C_g}{\ell^2}\left(V_g - V_T - \frac{V_d}{2}\right)V_d$ in induced channel region

and $I_{ds} = \frac{\mu_e C_g}{2\ell^2}(V_g - V_T)^2$ in saturated region $\Big\}$ where $V_d > V_g - V_T$

$g_m = \mu_e C_g (V_g - V_T)/\ell^2$ in saturated region

Substituting values, $g_m = \frac{\mu_e C_g}{\ell^2}\sqrt{\frac{I_{ds}\cdot 2\ell^2}{\mu_e C_g}} = \frac{1}{\ell}\sqrt{2 I_{ds}\cdot \mu_e \cdot C_g}$

Hence; $C_g = (\ell g_m)^2 / (2 I_{ds}\,\mu_e) = \frac{(10\times10^{-6}\cdot 2\times10^{-3})^2}{(2.5\times10^{-3}\cdot 0.13)} = \underline{0.37\text{ pF}}$ #.