ECE321L HW 8 Solution

3.25. From given conditions,

$V_{tp} = -0.4$, $K_p = 50\,\mu A/V^2$, $W/L = 8$, $P_R = 10\,\mu W$.

$$P_r = \frac{\Delta V^2}{R} = \frac{(2.2 - V_S)^2}{R} = 10\,\mu W$$

$$\therefore\quad R = \frac{(2.2 - V_S)^2}{10\,\mu W} \quad \text{——— ①}$$

Transistor is biased at the boundary.

$$\therefore\quad V_{DS} = V_{GS} - V_{tp} \Rightarrow V_D - V_S = V_G - V_S - V_{tp}$$

$$V_G = V_{tp} + V_D = 0.5 - 0.4 = 0.1\ V$$

Also,
$$|I_D| = \frac{K_p'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{tp})^2 = \frac{K_p'}{2}\left(\frac{W}{L}\right)(V_G - V_S - V_{tp})^2$$

$$= \frac{50\,\mu A/V^2}{2}(8)(0.1 - V_S - (-0.4))^2 = \frac{50\,\mu A/V^2}{2}(8)(0.5 - V_S)^2 \quad \text{— ②}$$

Also
$$|I_D| = \frac{2.2 - V_S}{R} \xrightarrow{\text{Combine ①}} \frac{2.2 - V_S}{\frac{(2.2 - V_S)^2}{10\,\mu W}} = \frac{10\,\mu W}{2.2 - V_S} \quad \text{——— ③}$$

$\because$ ② = ③, $|I_D| = |I_D|$

$$\therefore\quad \frac{50\,\mu A/V^2}{2}(8)(0.5 - V_S)^2 = \frac{10\,\mu W}{2.2 - V_S}$$

Get $V_S = 0.6815\ V$, $\because V_S > V_D$, $\therefore V_S \neq 0.336\ V$.

From ①,
$$R = \frac{(2.2 - V_S)^2}{10\,\mu W} = \frac{(2.2 - 0.6815)^2}{10\,\mu W} = \underline{230.6\ k\Omega}$$

3.26

(a) $V_{GS} = V_G - V_S = 0 - V_S$

Assume saturation,

$$|I_{DS}| = \frac{7.5\,mA}{2}(5)(-V_S + 0.6)^2 = \frac{3 - V_S}{4\,k\Omega} = I_{DS}$$

$$\therefore \frac{3 - V_S}{4\,k\Omega} = (187.5 \cdot 10^{-4})(V_S^2 - 1.2V_S + 0.36)$$

$\therefore$ $\underline{V_S = 1.842\,V}$. $\because$ for PMOS $V_S > V_G$.

(b) $$I_{DS} = \frac{3 - V_S}{4\,k\Omega} = \frac{3 - 1.842}{4\,k\Omega} = 289.5 \cdot 10^{-4}\,A$$

$$I_{DS} = \frac{V_D}{2\,k\Omega} \Rightarrow V_D = (2\,k\Omega)(289.5 \cdot 10^{-4}) = 0.579\,V$$

$$|V_{DS}| > |V_{GS}| - |V_{Tp}|$$

$1.263 > 1.242$, So saturation is true.

Thus, $\underline{V_D = 0.579\,V}$

3.30

$V_{GS} = V_G - V_S = 0 - (-1) = 1\ V$

Since $V_{DS} > V_{GS} - V_{Tn}$, i.e. $(2 > 1 - 0.6)$

$\therefore$ NMOS is in Saturation,

$\therefore I_{DS} = \frac{K_n}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{Tn})^2 = \frac{200 \cdot 10^{-6}}{2}(3) \cdot (1-0.6)^2$

$= 48\ \mu A$

$R_1 = \frac{V_{DD} - V_D}{I_{DS}} = \frac{3-1}{48\mu A} = \underline{41.67\ k\Omega = R_2}$

3.35

$V_G = V_D = V_O \Rightarrow V_{DS} = V_{GS}$

Transistor is saturated because drain & gate are connected.

$I_{DS} = \frac{K_n'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{Tn})^2 = \frac{90\mu A}{2}(10)(V_{DS} - 0.5)^2$

$I_{DS} = \frac{2.5 - V_D}{5K} = \frac{V_S}{2K} = I_{DS} \Rightarrow V_D - V_S = V_{DS} = 2.5 - 5I_{DS} - 2I_{DS}$

$\therefore I_{DS} = \frac{90\mu A}{2}(10)(2.5 - 5 \cdot I_{DS} - 2 \cdot I_{DS} - 0.5)^2 = 0$

Then get. $I_D = 192.32\ \mu A$, or $I_D = 424.46\ \mu A$

Since it is saturation, $\underline{I_D = 192.32\ \mu A}$

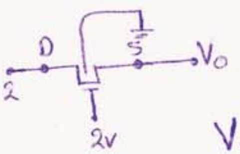
For V_O, $I_D = \frac{2.5V - V_O}{5k\Omega} \Rightarrow V_O = 2.5V - I_D(5k\Omega)$

$V_O = 2.5 - (192.32\ \mu A)(5k\Omega) = \underline{1.54\ V}$

3.37 $V_T = V_{T0} + \gamma\left(\sqrt{|2\phi_F + V_{SB}|} - \sqrt{|2\phi_F|}\right)$

$$\sqrt{|2\phi_F + V_{SB}|} = \sqrt{|2\phi_F|} + \frac{V_T - V_{T0}}{\gamma} \longrightarrow V_{SB} = \left(\sqrt{|2\phi_F|} + \frac{V_T - V_{T0}}{\gamma}\right)^2 - |2\phi_F|$$

$V_{SB} = 86.17\,mV \longrightarrow V_{BS} = -86.17\,mV$

3.38 

$$V_T = V_{T0} + \gamma\left(\sqrt{2\phi_F + V_{SB}} - \sqrt{2\phi_F}\right)$$

$$\left.\begin{array}{l} V_T = 0.6V + 0.25\left(\sqrt{0.7 + V_o} - \sqrt{0.7}\right) \\ (\text{Maximum } V_o) = V_{dd} - V_T \longrightarrow V_T = 2 - V_o \end{array}\right\} \Rightarrow \begin{array}{l} V_o = 1.26\,V \\ V_T = 0.74\,V \end{array}$$