EHB 335E HW #3 Solutions

① $I_{D1} = k_n (V_{GS} - V_{TH})^2 = 15 \frac{mA}{V^2} (0 + 1.7)^2 V = 43.35 mA$

$R_L = \infty$

$V_{o,max} = V_{CC} - V_{CE(sat)} = 5 - 0.25 = 4.75 V$

Assume $V_{DS} = V_{GS} - V_{TH} = 1.7 V$

$V_{o,min} = -5 + V_{D,sat} = -3.3 V$

$R_L = 400 \Omega$

$V_{o,max} = 4.75 V$

$V_{o,min} \Rightarrow I_{L max} = \frac{-3.3 V}{400} = -8.25 mA < 43.35 mA$

The transistor can supply the necessary current, hence, $V_{o min} = -3.3 V$ as well

b) For $V_o = 2.5 V$ and $i_{max} = 43.35 mA$

$$R_{L min} = \frac{V_o}{i_{max}} = \frac{2.5 V}{43.35 mA} = 57.67 \Omega$$

c) $P_L = \frac{V_o^2}{2 R_L} = \frac{(2.5)^2 V}{2 \cdot 57.67 \Omega} = 54.18 mW$

$P_{DC} = (5 - (-5)) \times 43.35 = 433.35 mW$

$$\eta = \frac{P_L}{P_{DC}} = \frac{54.18 mW}{433.35 mW} = 12.5\%$$

② $i_L = \frac{25 V}{8 \Omega} = \boxed{3.125 A = i_N}$

a) $i_{B,N} = \frac{3.125 A}{51} = 61.3 mA$

$i_{R_1} = 61.3 mA + 24 mA = 85.3 mA$

$V_{BE} = V_T \cdot \ln\left(\frac{i_N}{i_S}\right) = 25.9 mV \ln\left(\frac{3.125}{7 \times 10^{-12}}\right) = 0.694 V$

$85.3 mA = \frac{30 - 0.694 - 24}{R_1} \Rightarrow \boxed{R_1 = 62.2 \Omega}$

$V_D = 0.0259 \ln\left(\frac{24 mA}{7 \times 10^{-12}}\right)$

$V_D = 0.569 V$

$V_{ED} = 2 V_D - V_{BE}$

$= 2 \cdot 0.569 - 0.694$

$= 0.443 V$

$i_p = 7 \times 10^{-12} \exp\left(\frac{0.443}{25.9 mV}\right) = \boxed{0.19 mA}$

b) $V_{BE,N}(old) = 0.694 V$

$i_{R_1} = \frac{30 - V_{BE,N}}{62.2} = 0.47 A$

$V_{BE,new} = 25.9 mV \ln\left(\frac{0.47 A}{7 \times 10^{-12}}\right) = 0.65 V$

Neglecting the base currents $\Rightarrow I_{D1} = I_{D2} = 0.47 mA$

if diodes & transistors are matched $\Rightarrow I_n = I_p = 0.47 mA$

3) If $V_I = -1.6\,V$ & $V_o = 0\,V \Rightarrow V_{SG2} = 1.6V = V_{GS1}$

a)

$$i_{D1} = i_{D2} = 0.4 = \frac{0.12}{2}\left(\frac{W}{L}\right)_1 (1.6 - 0.75)^2 \Rightarrow \left(\frac{W}{L}\right)_1 = 9.23$$

$$0.4 = \frac{0.05}{2}\left(\frac{W}{L}\right)_2 (1.6 - 0.75)^2 \Rightarrow \left(\frac{W}{L}\right)_2 = 22.15.$$

For M_3 & M_4 $\quad 0.2 = \frac{0.12}{2}\left(\frac{W}{L}\right)_3 (1.6 - 0.75)^2 \Rightarrow \left(\frac{W}{L}\right)_3 = 4.61$

$$0.2 = \frac{0.05}{2}\left(\frac{W}{L}\right)_4 (1.6 - 0.75)^2 = \left(\frac{W}{L}\right)_4 = 11.1$$

b) $V_{o,max} = V^+ - V(I_{BIAS}) - V_{GS1} = 10 - 0.2 - 1.6\,V = 8.2\,V$

$V_{o,min} = V^- + |V_{gs2}| = -10 + 1.6\,V = -8.4\,V$