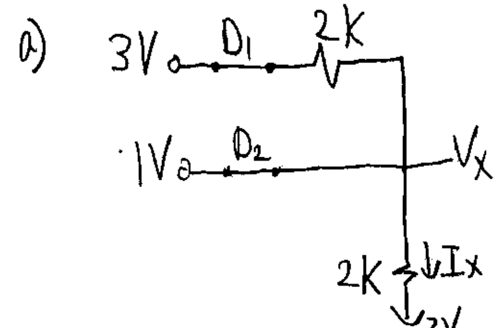
①

EECE 2412: HW3 Solutions

Problem 1:

a)



$I_x = \frac{1V-(-3V)}{2K} = \boxed{2mA = I_x}$

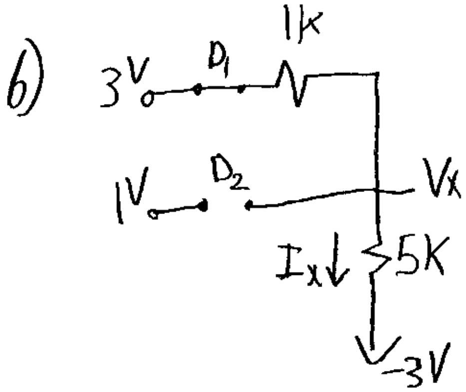
$\boxed{V_x = 1V}$

checks:

$I_{D1} = \frac{3V - 1V}{2K} = 1mA > 0$ → D_1 is forward-biased (FB)

$I_{D_2} = I_x - I_{D_1} = 1mA$ → D_2 is forward-biased (FB)

b)



$I_x = \frac{3V-(-3V)}{5K + 1K} = \boxed{1mA = I_x}$

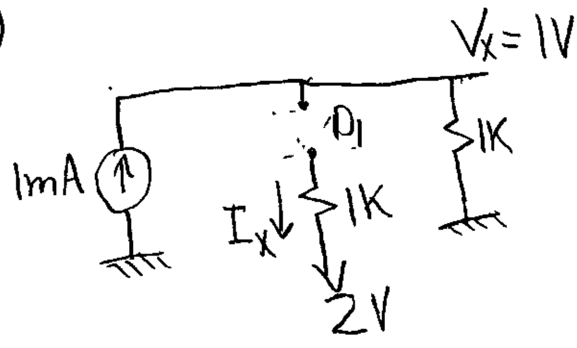
$V_x = 3V - I_x * 1K = \boxed{2V = V_x}$

Checks:

$V_{D2} = 1V - 2V = -1V < 0.7V$ → D_2 is reverse-Biased (RB)

$I_{D1} = I_x = 1mA > 0$ → D_1 is Forward-Biased (FB)

c)



$V_x = 1mA \times 1K\Omega = \boxed{1V = V_x}$

$\boxed{I_x = 0A}$

checks:

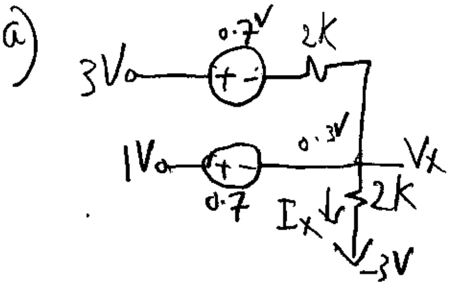
$V_{D1} = 1V - 2V = -1V < 0.7V$

→ D_1 is reverse-biased (RB)

②

Problem 2:

a)



$V_x = 1 - 0.7 = \boxed{0.3\,V = V_x}$

$I_x = \dfrac{0.3V - (-3V)}{2K} = \boxed{1.65\,mA = I_x}$

Checks:

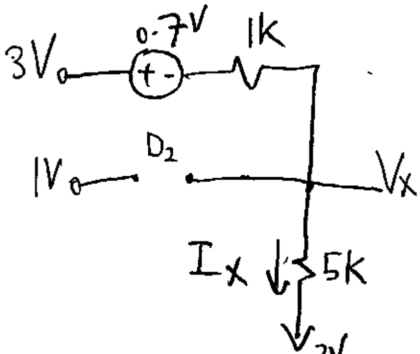
$I_{D1} = \dfrac{3V - 0.7V - 0.3V}{2K} = 1mA > 0$

$\rightarrow D_1$ is Forward-biased (FB)

$I_{D2} = I_x - I_{D1} = 0.65mA > 0$

$\rightarrow D_2$ is Forward-biased (FB)

b)



$I_x = \dfrac{3V - 0.7V - (-3V)}{1K + 5K} = \boxed{0.883\,mA = I_x}$

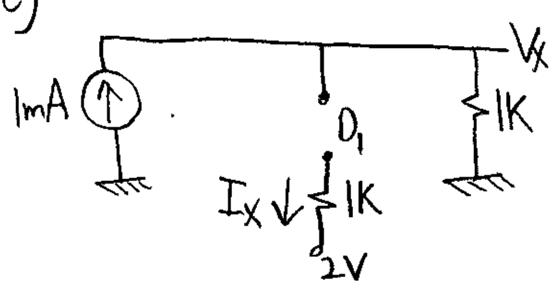
$V_x = 3V - 0.7V - 1K * I_x = \boxed{1.4167\,mV = V_x}$

checks:

$V_{D2} = 1V - V_x = -0.46 \rightarrow D_2$ is reverse-biased (RB)

$I_{D1} = I_x = 0.883mA > 0 \rightarrow D_1$ is Forward-biased (FB)

c)



$V_x = 1mA \times 1K = \boxed{1V = V_x}$

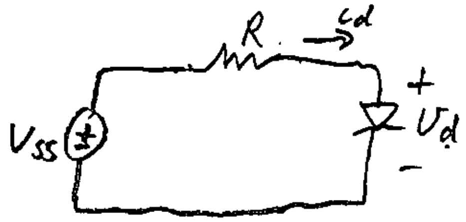
$\boxed{I_x = 0\,mA}$

Checks:

$V_{D1} = V_x - 2V = -1V < 0$

$\rightarrow D_1$ is reverse-biased (RB)

③



Problem 3

KVL: $0 = -V_{SS} + R \cdot i_d + v_d$

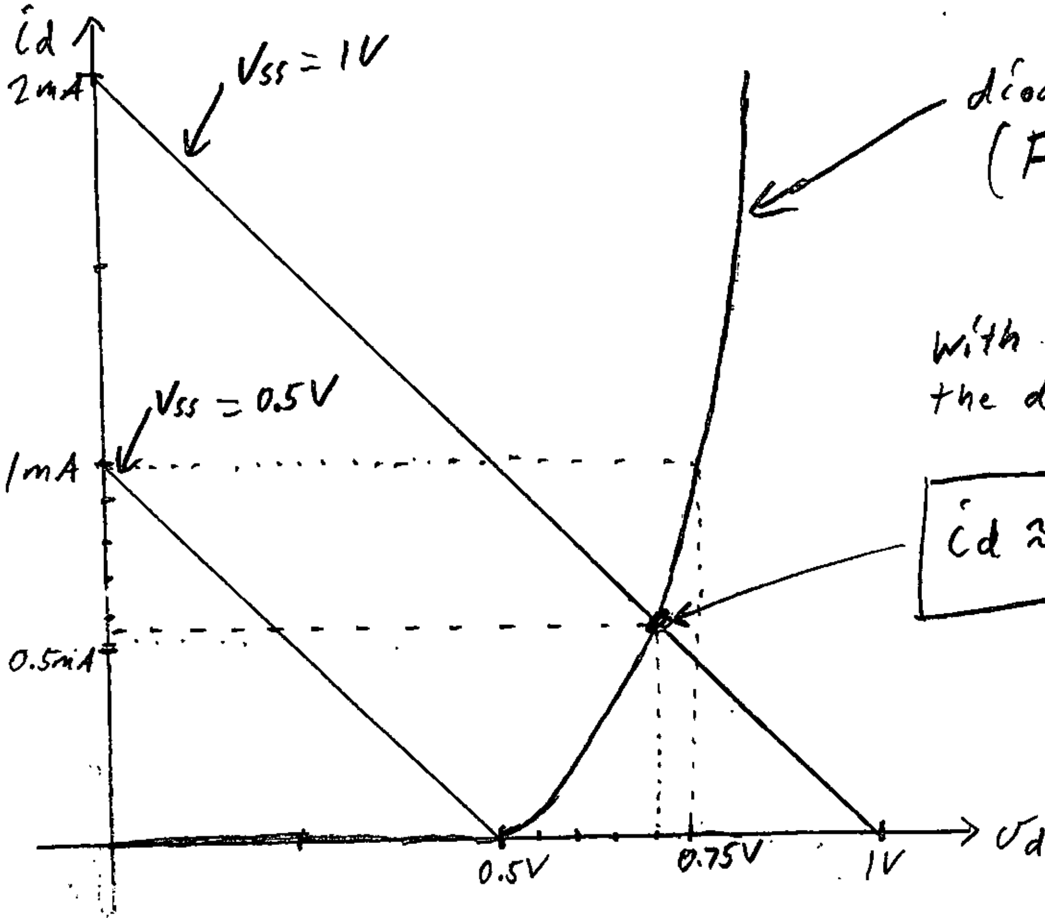
$\hookrightarrow \ i_d = \frac{V_{SS} - v_d}{R} = \frac{V_{SS}}{R} - \frac{v_d}{R}$

with $V_{SS} = 1V$ and $R = 500\,\Omega$: $\quad i_d = \frac{1V}{500\Omega} - \frac{v_d}{500\Omega} = 2\,mA - v_d \cdot 2\frac{mA}{V}$

with $V_{SS} = 0.5V$ and $R = 500\,\Omega$: $\quad i_d = 1mA - 2\frac{mA}{V}$

$\hookrightarrow$ slope of the load line in both cases: $\boxed{-\frac{2\,mA}{V} = -\frac{1}{R}}$

$\hookrightarrow$ **No, the slope does not change when V_{SS} changes.**



diode characteristics (Fig. 3.9d)

with $V_{SS} = 1V$ and the diode characteristic

$\boxed{i_d \approx 0.55\,mA}$

4

Prob. 4

a) $50°C = 323\,K$

equation 3.16 in the book:

$$V_T = \frac{k \cdot T}{q} = \frac{(1.38\times10^{-23})\cdot(323)}{1.60\times10^{-19}} = 27.86\,mV$$

equation 3.15 in the book:

$$I_D = I_S \cdot \left[e^{\left(\frac{V_D}{n\cdot V_T}\right)} - 1\right] \longrightarrow V_D = n\cdot V_T \cdot \ln\left(\frac{I_D}{I_S}+1\right)$$

Since $\frac{I_D}{I_S} >> 1$ is assumed here:

(1): $V_D \approx n \cdot V_T \cdot \ln\left(\frac{I_D}{I_S}\right)$

Using the two given measurement results to determine the emission coefficient:

$$V_{D2} - V_{D1} = n\cdot V_T \cdot \ln\left(\frac{I_{D2}}{I_S}\right) - n\cdot V_T \cdot \ln\left(\frac{I_{D1}}{I_S}\right)$$

$$V_{D2} - V_{D1} = n\cdot V_T \cdot \ln\left(\frac{I_{D2}}{I_{D1}}\right)$$

$$0.6 - 0.5 = n\cdot(27.86\times10^{-3})\cdot \ln\left(\frac{120\times10^{-6}}{7\times10^{-6}}\right)$$

$$\rightarrow \boxed{n = 1.263}$$

b) Rearranging equation (1) above:

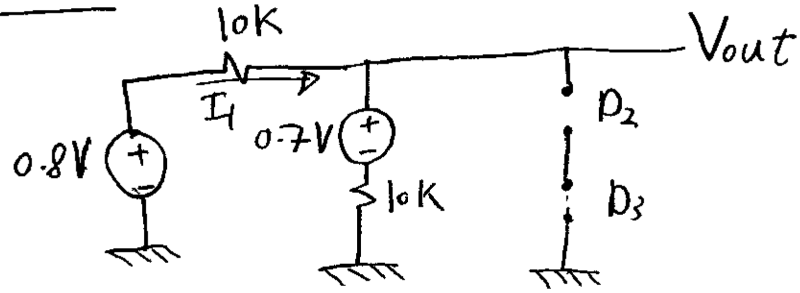
$$I_S = \frac{I_D}{e^{\frac{V_D}{n\cdot V_T}}} = \frac{\times 10^{-6}}{e^{\frac{0.5}{(1.263)\cdot(27.86\times10^{-3})}}}$$

$$\boxed{I_S = 4.728\times10^{-12}\,A = 4.728\,pA}$$

(5)

Problem 5:

a)



Using KVL

$$0.8V - I_1 * 10K - 0.7V - I_1 * 10K = 0$$

$$I_1 = 5\mu A$$

$$V_{out} = 0.8V - I_1 * 10K = \boxed{0.75V = V_{out}}$$

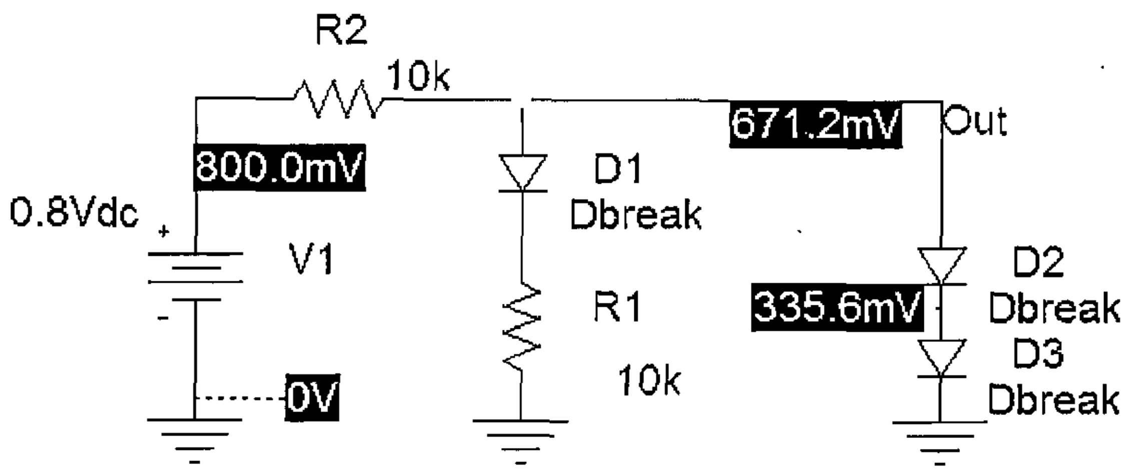
Checks:

$I_{D_1} = I_1 > 0 \rightarrow D_1$ is Forward-biased (FB)

$V_{D_1} + V_{D_2} = 0.75V < 1.4V \rightarrow D_2, D_3$ are reverse-biased (RB)

Problem 5, Part b)

Verification with V1 = 0.8V:



Part c) Transfer characteristic: