Digital Electronics Spring 2020 Midterm Exam 05/01/2020

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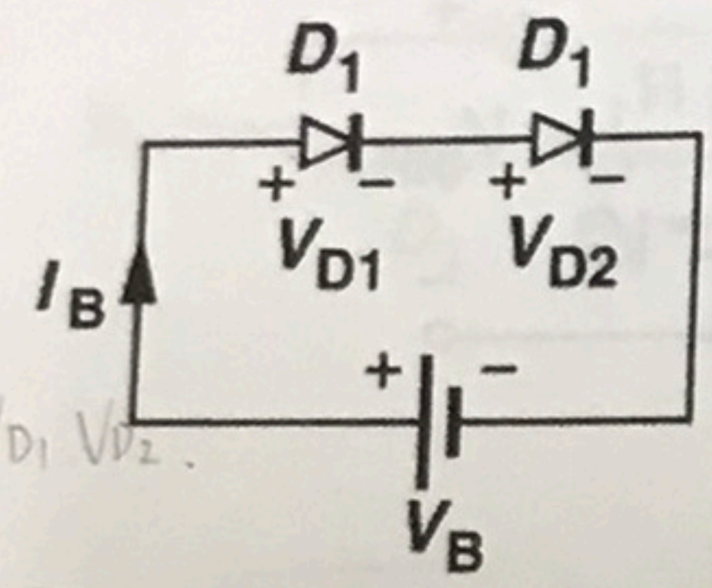
1. (15%) Two diodes with reverse saturation currents of I_{S1} and I_{S2} placed series. Calculate I_B , V_{D1} , and V_{D2} in terms of V_B , I_{S1} , and I_{S2} . $I_D = I_S \exp(V_D / V_T)$ $V_T = 26\text{mV}$



$I_B \; V_{D1} \; V_{D2}$

$V_B \; I_{S1} \; I_{S2}$

$I_B = I_{D1} = I_{D2}$

$V_B = V_{D1} + V_{D2}$

$= V_T \ln \frac{I_B}{I_{S1}} + V_T \ln \frac{I_B}{I_{S2}}$

$= V_T \ln \left(\frac{I_B^2}{I_{S1} I_{S2}} \right)$

$I_B = e^{\frac{V_B}{2V_T}} \sqrt{I_{S1} I_{S2}}$

$= e^{\frac{V_B}{0.052}} \sqrt{I_{S1} I_{S2}}$ #

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$I_B = I_{S1} \exp\left(\frac{V_{D1}}{V_T}\right)$

$\frac{I_B}{I_{S1}} = \exp\left(\frac{V_{D1}}{V_T}\right)$

$\ln\left(\frac{I_B}{I_{S1}}\right) = \frac{V_{D1}}{V_T}$

$V_{D1} = V_T \ln\left(\frac{I_B}{I_{S1}}\right)$

$= 0.026 \times \ln\left(\frac{e^{\frac{V_B}{0.026}} \sqrt{I_{S1} I_{S2}}}{I_{S1}} \right)$

$= 0.026 \times \left(\ln e^{\frac{V_B}{0.026}} + \ln \frac{\sqrt{I_{S1} I_{S2}}}{I_{S1}} \right)$

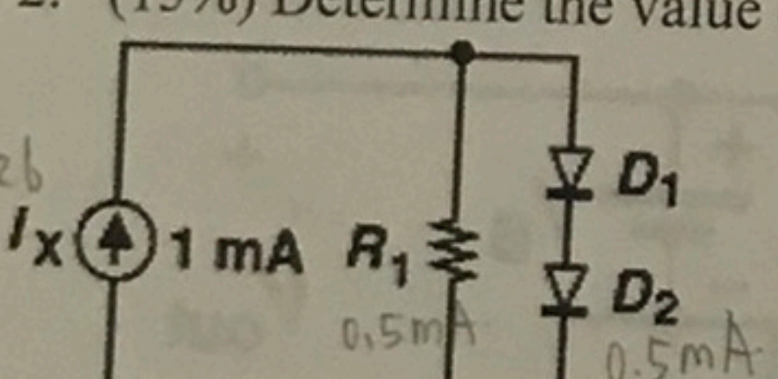
$= 0.026 \left(\frac{V_B}{0.026} + \ln \sqrt{\frac{I_{S2}}{I_{S1}}} \right)$

$= \frac{V_B + 0.026 \ln \sqrt{\frac{I_{S2}}{I_{S1}}}}{2}$ #

$V_{D2} = \frac{V_B}{2} + 0.026 \ln \sqrt{\frac{I_{S1}}{I_{S2}}}$ #

2. (15%) Determine the value of R_1 such that R_1 carries 0.5mA. Assume $I_S = 5 \times 10^{-16}$ A for each diode.

$V_T = 0.026$



$I_{D1} = I_{D2} = 1 - 0.5 = 0.5\text{mA}$

$I_D = I_S \exp\left(\frac{V_D}{V_T}\right)$

$0.5 \times 10^{-3} = 5 \times 10^{-16} \times e^{\frac{V_D}{0.026}}$

$e^{\frac{V_D}{0.026}} = \frac{5 \times 10^{-4}}{5 \times 10^{-16}} = 10^{12}$

$\frac{V_D}{0.026} = \ln 10^{12}$

$V_D = 0.026 \times \ln 10^{12}$

$\doteqdot 0.026 \times 27.63$

$= 0.71838$

$\doteqdot 0.7V$

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$V_{R1} = V_{D1} + V_{D2}$

$= 0.7 \times 2$

$= 1.4$

$R_1 = \frac{1.4}{0.5 \times 10^{-3}}$

$= \frac{2.8}{10^{-3}}$

$= 2800\,\Omega$ #

3. (10%) Plot the input/output characteristics of the circuit shown below using an ideal model for the diode. (Assume V_B =2V).

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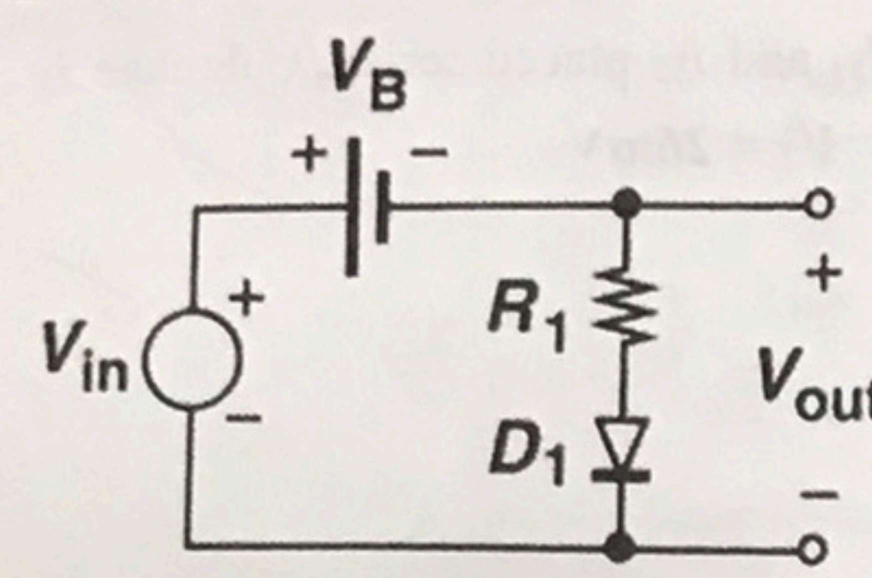
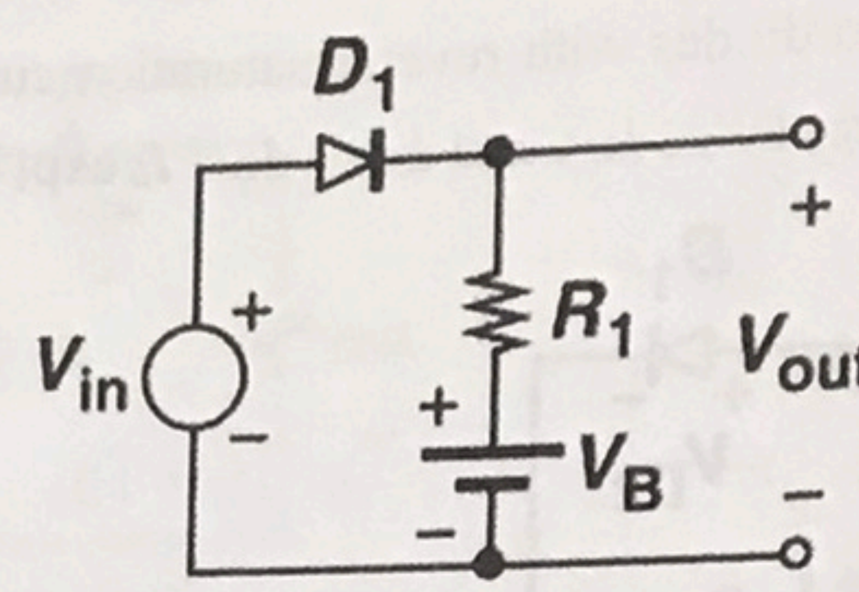


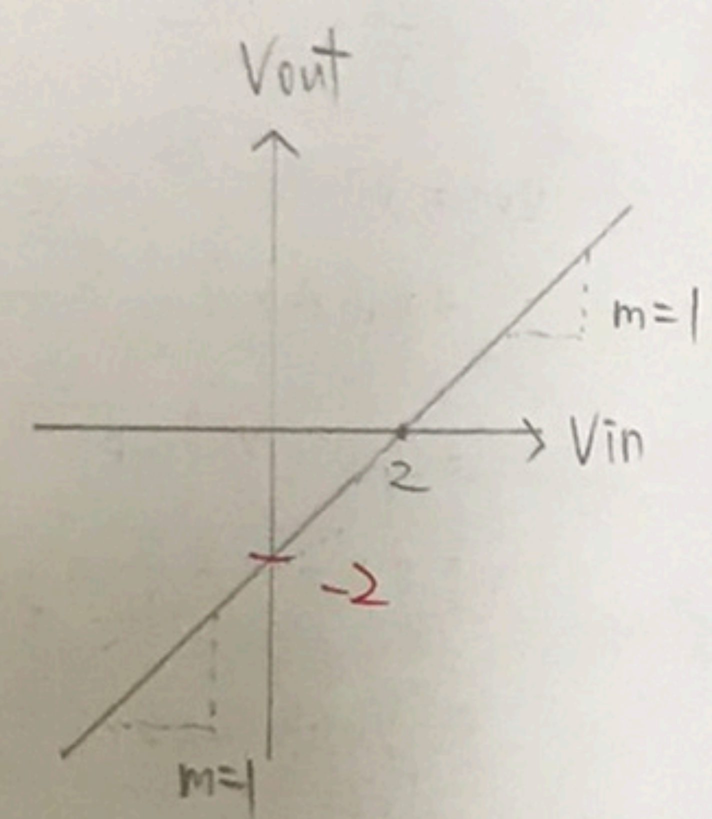


$\boxed{D_1 \text{ off}}$

$V_{out} = V_{in} - V_B$
$= V_{in} - 2$

$\boxed{D_1 \text{ on}}$

$V_{out} = V_{in} - V_B$
$= V_{in} - 2$

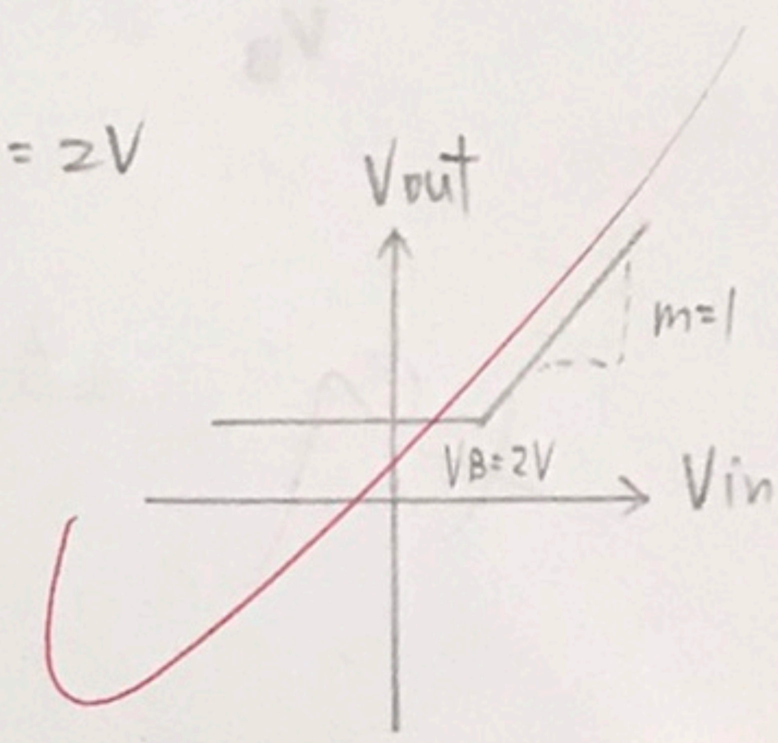


$\boxed{D_1 \text{ off}}$

$V_{out} = V_B = 2V$

$\boxed{D_1 \text{ on}}$

$V_{out} = V_{in}$



4. (10%) Assume constant voltage diode model, plot I_{R1} as a function of I_{in} for the circuits shown below. (Assume V_B =2V).

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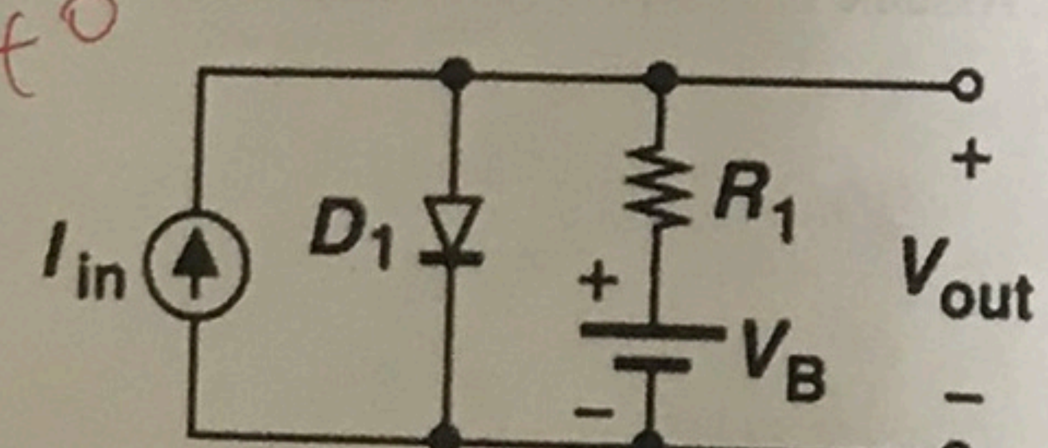
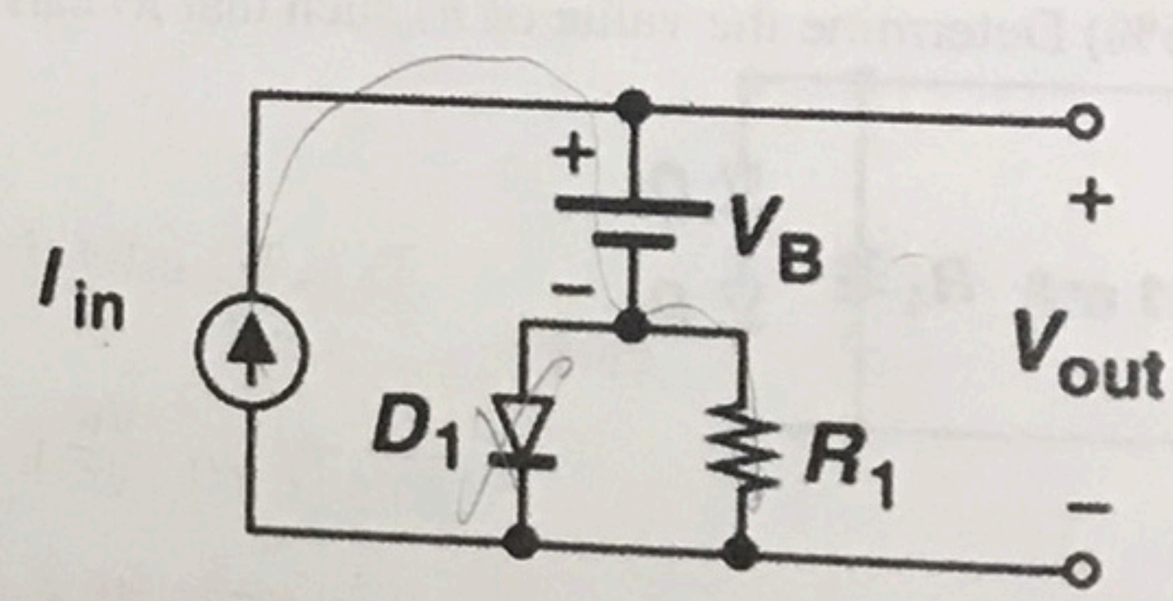




$\boxed{D_1 \text{ off}}$

$I_{in} = I_{R1}$

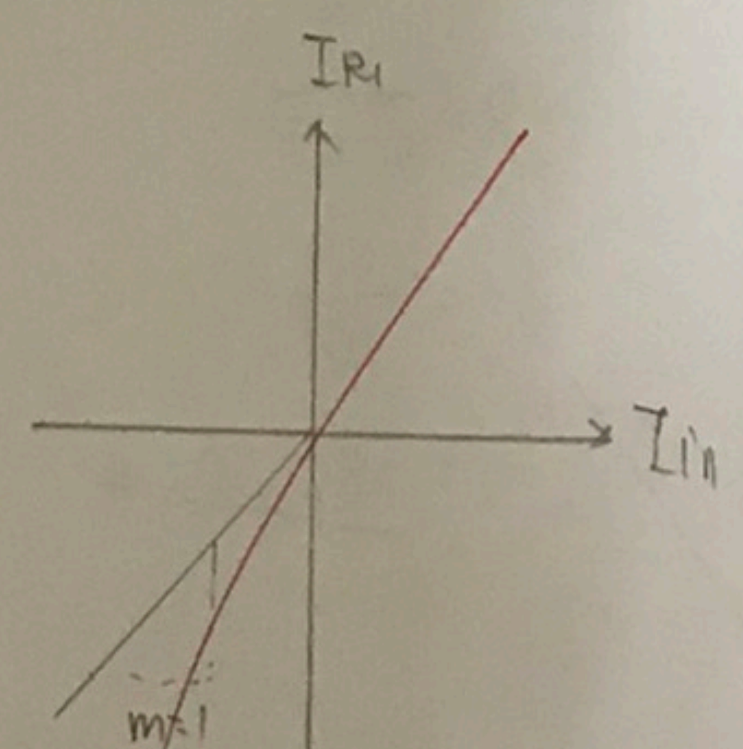
$\boxed{D_1 \text{ on}}$

$V_{D,on} = V_{R_1} + V_B$

$V_{D.on} = I_{R_1} R_1 + V_B$

$I_{R_1} = \frac{V_{D.on} - V_B}{R_1}$

$= \frac{V_{D.on} - 2}{R_1}$

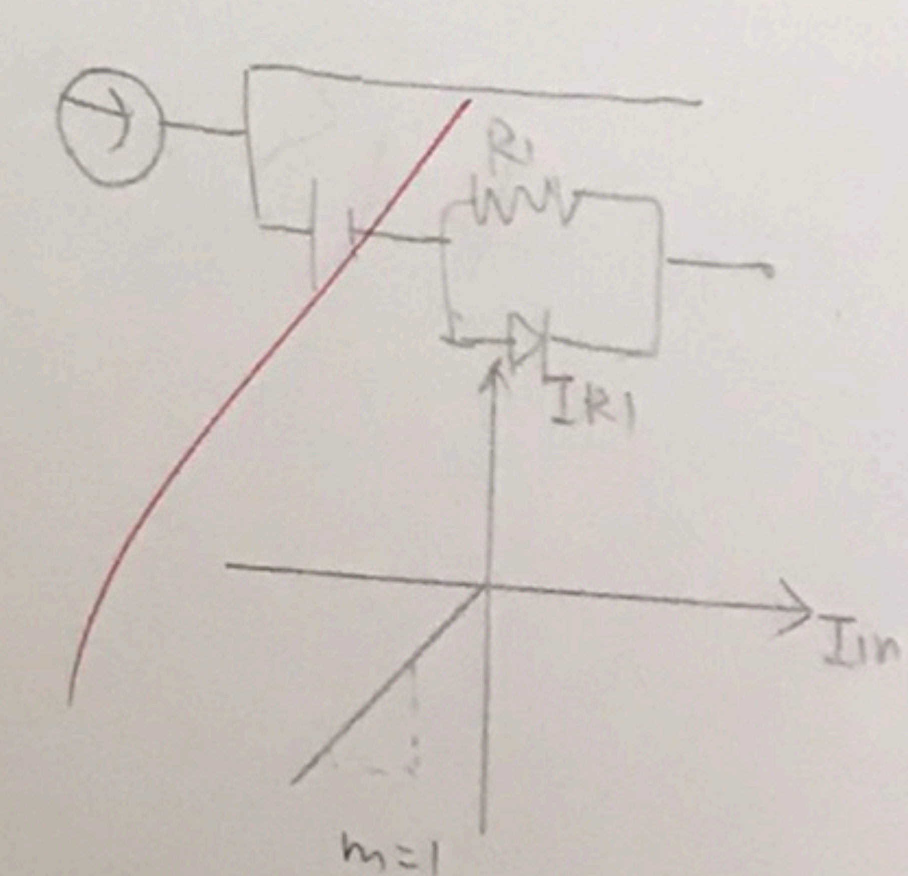


$\boxed{D_1 \text{ off}}$

$I_{in} = I_{R1}$

$\boxed{D_1 \text{ on}}$

$V_{D.on} = I_{R1} R_1$



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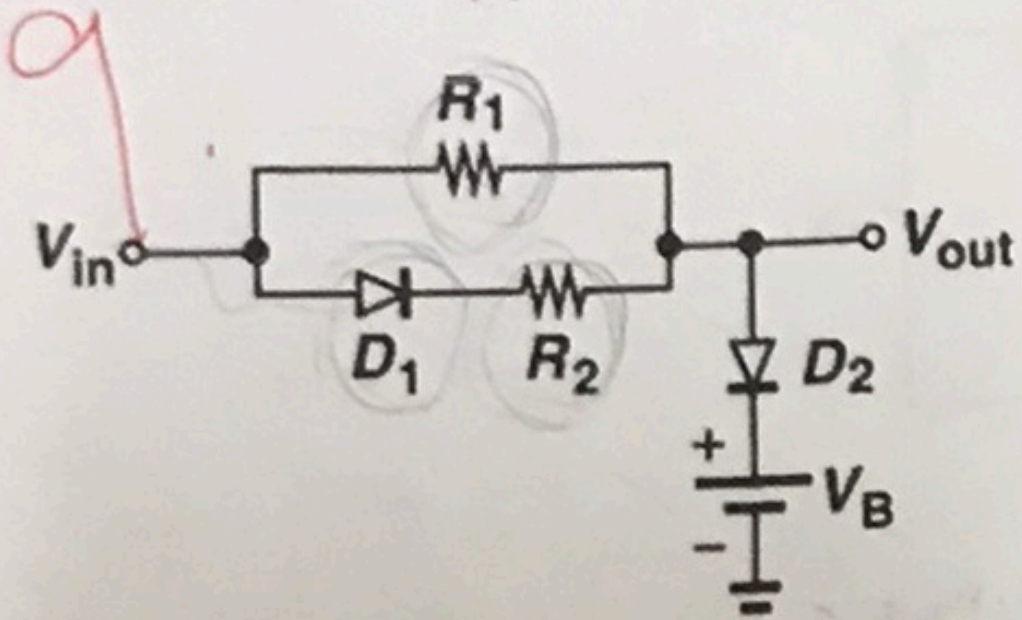
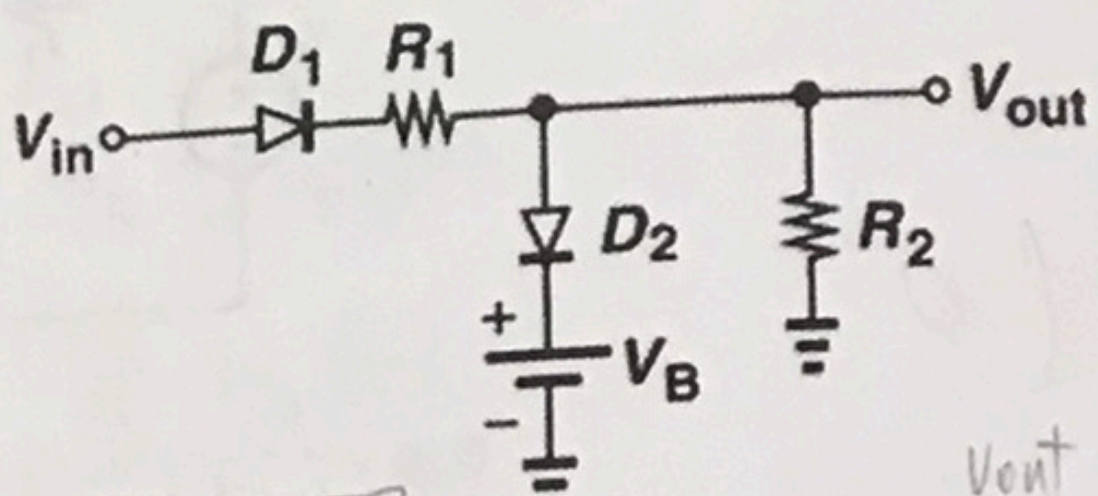
5. (15%) Plot the input/output characteristics of the circuit illustrated in Fig. 3.76 assuming a constant voltage model and $V_B = 2$ V.

(a)



(b)



$V_{in} \to -\infty$, $\boxed{D_1 \text{ off}, D_2 \text{ off}}$

$V_{in} = V_{out}$

V_{in} 漸大 $\to$ $\boxed{D_1 \text{ on}, D_2 \text{ off}}$

$V_{D\,on} + V_{R_2} = V_{R_1}$

$V_{out} = V_{in} - V_{D\,on} - V_{R_2}$

$= V_{in} - V_{R_1} + V_{R_2} - V_{R_2}$

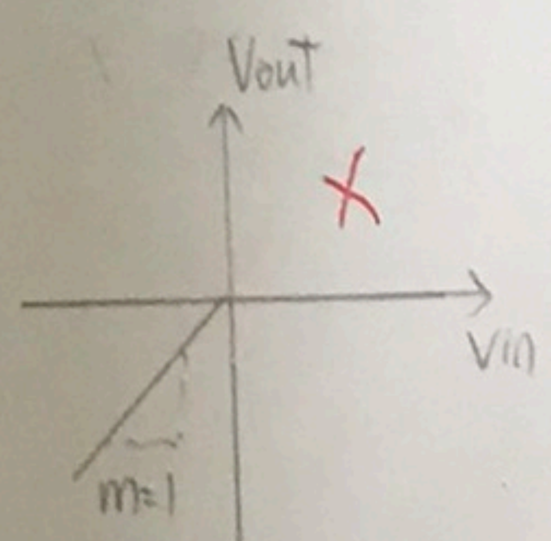
$= V_{in} - V_{R_1}$

$\boxed{D_1 \text{ on}, D_2 \text{ on}}$

$V_{in} = V_{D1} + V_{R_2} + V_{D2} + V_B$

$V_{out} = V_{D2} + V_B$

$= V_{in} - V_{D_1} + V_{R_2}$



$\boxed{D_1 \text{ off}, D_2 \text{ off}}$

$V_{in} = V_{out}$

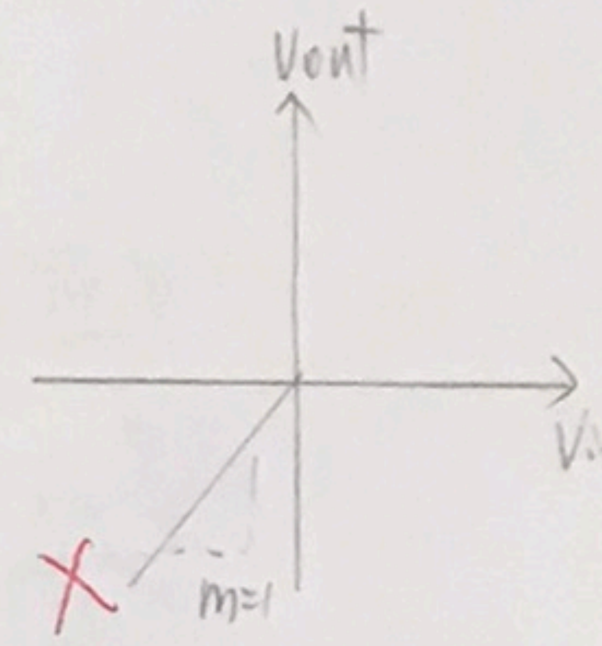
$\boxed{D_1 \text{ on}, D_2 \text{ off}}$

$V_{in} = V_{D_1,on} + V_{R_1} + V_{R_2}$

$V_{out} = V_{R_2}$

$= V_{in} - V_{D_1,on} - V_{R_1}$

$= V_{in} - V_{D_1,on} - IR_1$



6. (15%) Suppose the diodes carry a current of 5 mA and the load, a current of 20 mA. If the load current increases to 21 mA, what is the change in the total voltage across the three diodes? Assume R_1 is much greater than $3r_d$. $r_d = V_T / I_D$, $V_T = 26$mV

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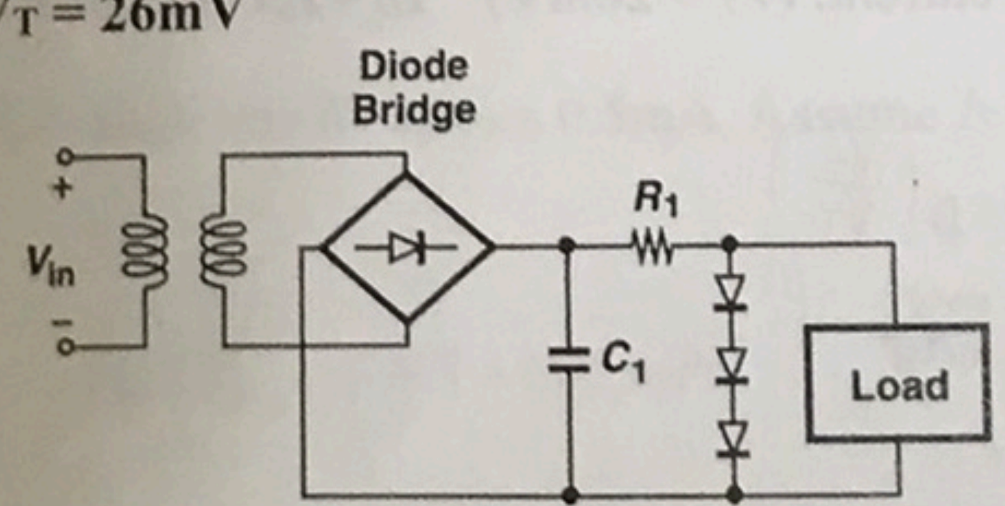


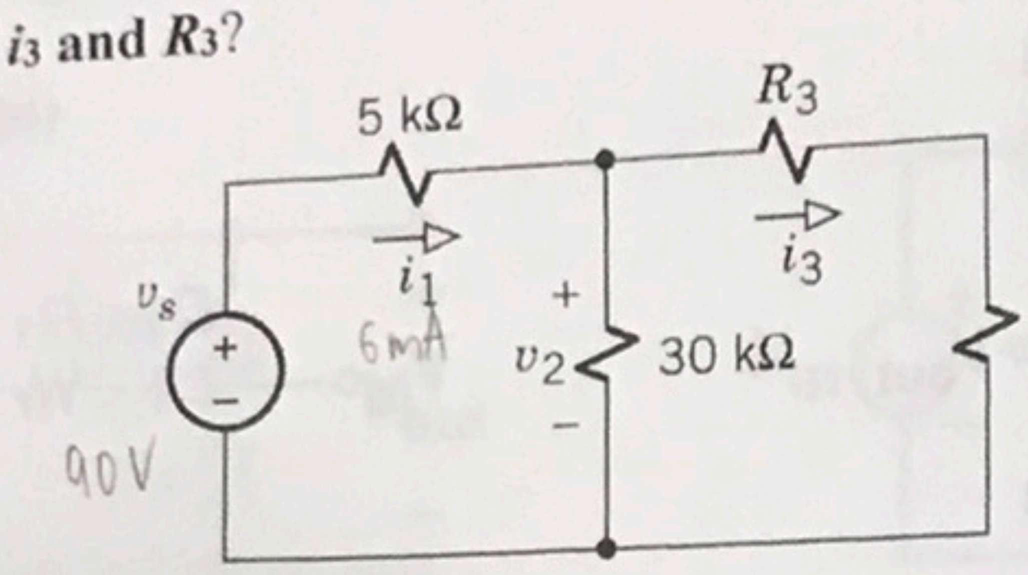
$r_d = \frac{V_T}{I_D} = \frac{0.026}{5 \times 10^{-3}} = 5.2$

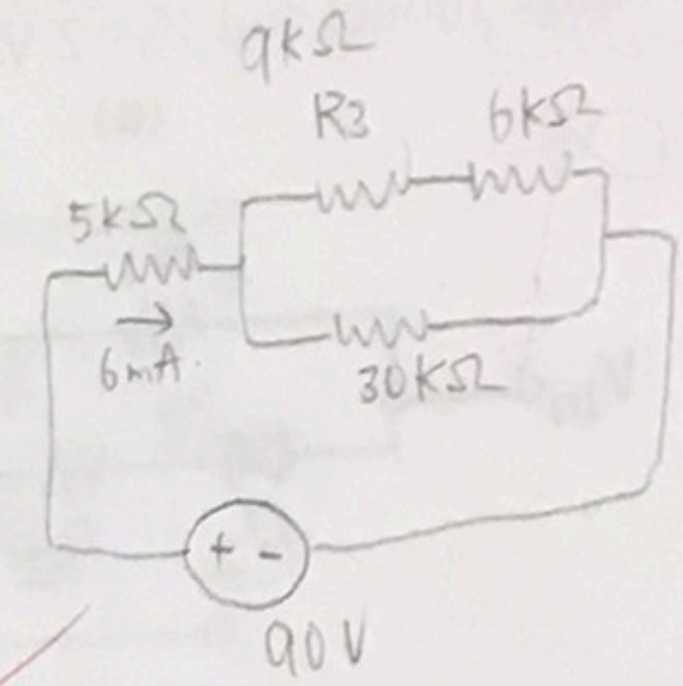
$\Delta V = (1 \times 10^{-3})(5.2 \times 3)$

$= 15.6 \times 10^{-3}$ V

$= 1.56 \times 10^{-4}$ V #

7. (10%) If the circuit in the following figure represents a source and load with v_s=90V, and i_1=6mA, then **what are the values of i_3 and R_3?**





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$R_{源} = \frac{90}{6\times10^{-3}} = 15000 = 15k\Omega$

$15 = 5 + \frac{1}{\frac{1}{R_3+6} + \frac{1}{30}}$

$\frac{1}{10} = \frac{1}{R_3+6} + \frac{1}{30}$

$\frac{1}{10} = \frac{30+R_3+6}{(R_3+6)30}$

$360+10R_3 = 30R_3+180$

$20R_3 = 180$

$R_3 = 9k\Omega$ #

$R_3 : R_{V_2} = 15 : 30 = 1:2$

$\Rightarrow I_{R_3} : I_{V_2} = 2:1$

$i_3 = 6\times\frac{2}{3} = 4mA$ #

8. (10%) Consider a *pn* junctions in forward bias. Initially a current of 5 mA flows through it, and the current increases by 8 times hen the forward voltage is increased by 1.5 times. Determine the initial bias applied and reverse saturation current. (V_T = 26mV) $I_D = I_S \exp(V_D / V_T)$ $V_T = 26mV$

$5\times10^{-3} = I_s \cdot \exp\left(\frac{V_D}{V_T}\right)$

$5\times10^{-3} = I_s \cdot e^{\frac{5\times10^{-3}}{0.026}}$

$I_s = \frac{5\times10^{-3}}{e^{\frac{5}{26}}}$

+2