Problem Set 1

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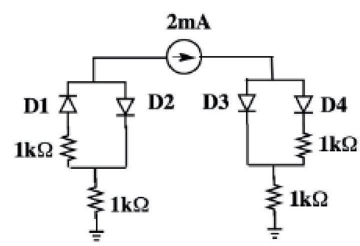
1. For the circuit shown below, find the voltage and current of each diode.



   (a) Assume the diodes are ideal.

   (b) Assume a 0.7V, constant voltage drop (CVD) diode model.

   (c) Assume a "1mA diode" exponential diode model (i.e., that V=0.7V when I=1mA). Assume thermal voltage $V_T = 25\text{mV}$.

Solution: Assuming ideal diodes, we assume D_3 is on and D_4 is off. This is because either needs to be on according to KCL. But if D_4 is on, there is a voltage drop across the 1kΩ resistor, meaning there is a voltage drop across D_3, so D_3 has to be on regardless. But if it is on, there should be no voltage drop across D_3. If D_4 is on, there there is no voltage drop across the resistor, which is impossible. Hence D_3 is on and D_4 is off.
Looking on the left hand side, D_1 has to be on as there is no other way for current to "enter" and reach 2mA. Then voltage across D_2 has a negative bias, so D_2 is off. Hence

Number/Measurement	Voltage (V)	Current (mA)
1	0	2
2	-2	0
3	0	2
4	0	0

With a 0.7V constant voltage drop, the same analysis applies, so D_1 and D_3 are on, and D_2 and D_4 are off. Then

Number/Measurement	Voltage (V)	Current (mA)
1	0.7	2
2	-2.7	0
3	0.7	2
4	0.7	0

For the 1mA model, we use

$$V_{D_1} - V_{D_2} = V_T \ln\left(\frac{I_{D_1}}{I_{D_2}}\right)$$

Putting $I_1 = 2, I_2 = 1, V_2 = 0.7$, we get $V_1 = 0.717$V, which is close to 0.7V as assumed in our previous model. On the other side, we have

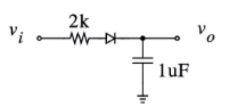
$$I_3 + I_4 = 2 \tag{1}$$

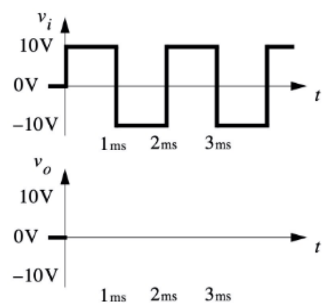
$$V_3 = V_4 + I_4 \tag{2}$$

$$V_T \ln\left(\frac{I_3}{I_4}\right) = V_3 - V_4 \tag{3}$$

One can use numeric methods to solve this.

2. For the circuit shown below, sketch the output waveform, $v_o(t)$ and find $v_o(t)$ at time $t = 3$ms. Assume the diode is ideal and the capacitor is initially discharged.





Solution: When voltage is positive, the diode behaves like a perfect conductor, so this becomes an RC circuit. When voltage is negative, the diode behaves like an open circuit. There is no current through the capacitor since there is no change in voltage. This is as if the RC circuit is paused. It resumes when voltage is positive again. Hence, for t from 0 to 1 ms, it follows $v_o(t) = V_\infty\left(1 - e^{-t/\tau}\right)$. From 1 ms to 2 ms, it is constant and equal to $v_o(1)$. From 2 ms to 3 ms, it resumes and obeys $v_o(t) = V_\infty\left(1 - e^{-(t-1)/\tau}\right)$.