Homework 3

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1. The following plots can be made for i versus V of the given circuits:

    (a) Circuit 1:

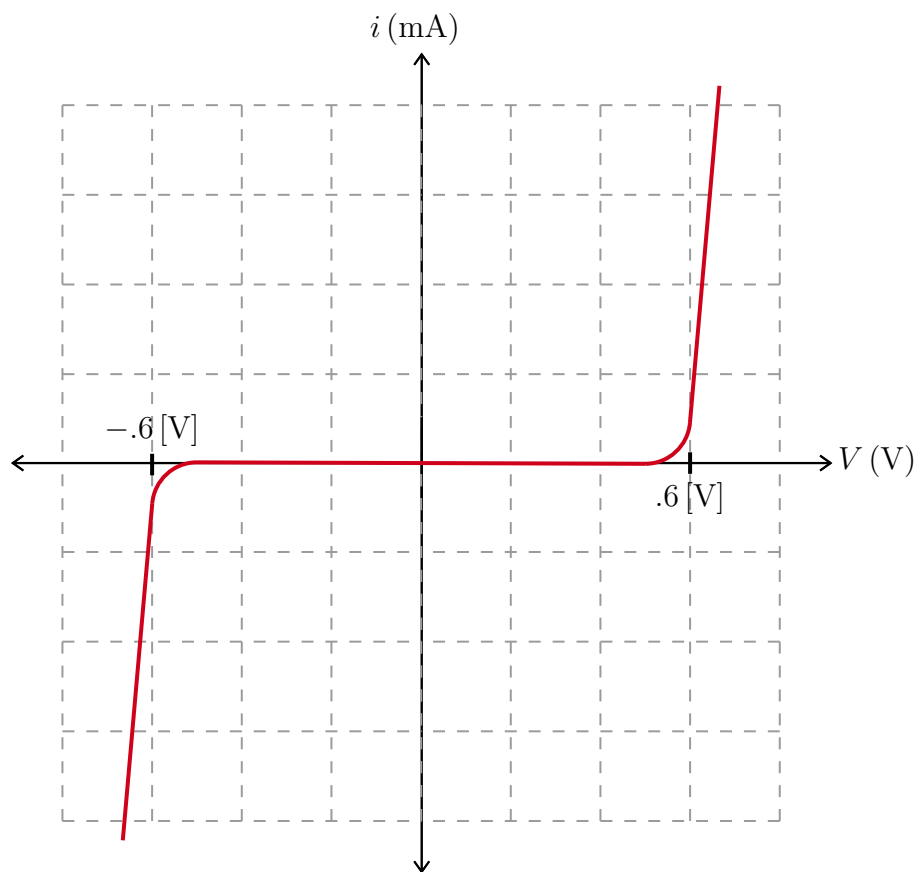Figure 1: Plot Showing Current-Voltage Relationship for Circuit 1

(b) Circuit 2 (we obtain the voltage values by summing $.6 + 6.8 = 7.4[V]$). Note, there is only a positive voltage response since a forward-biased diode is placed:
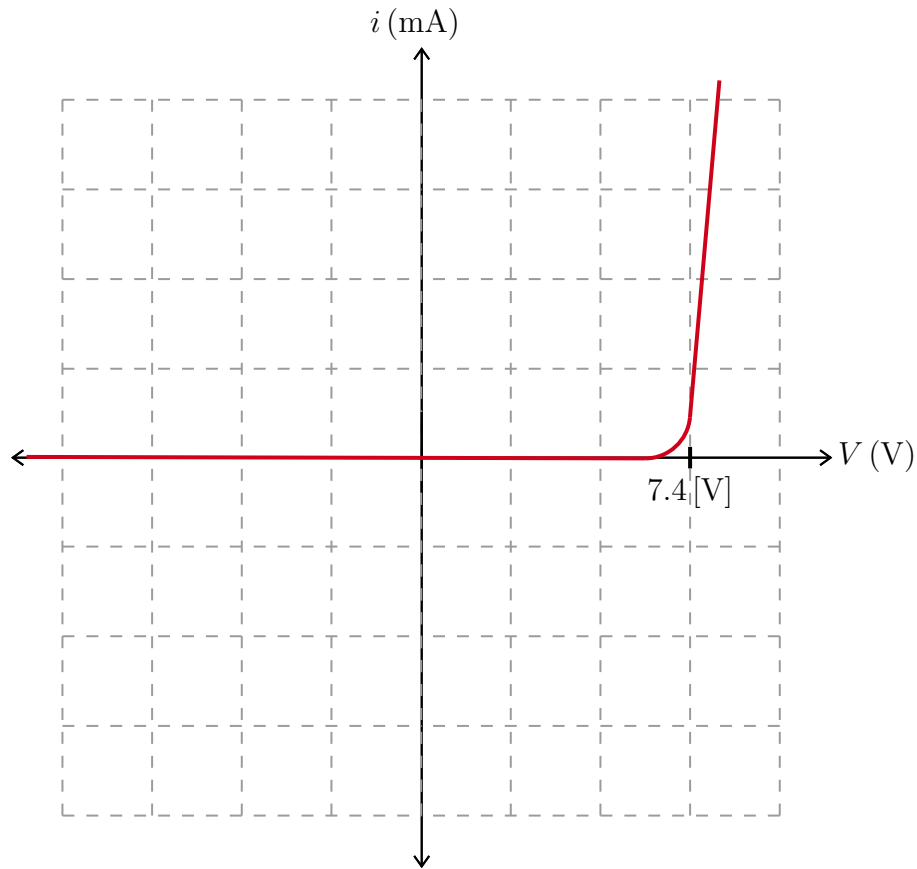

Figure 2: Plot Showing Current-Voltage Relationship for Circuit 2

(c) Circuit 3 (we obtain the voltage values by summing $5.6 + .6 = 6.2[V]$):
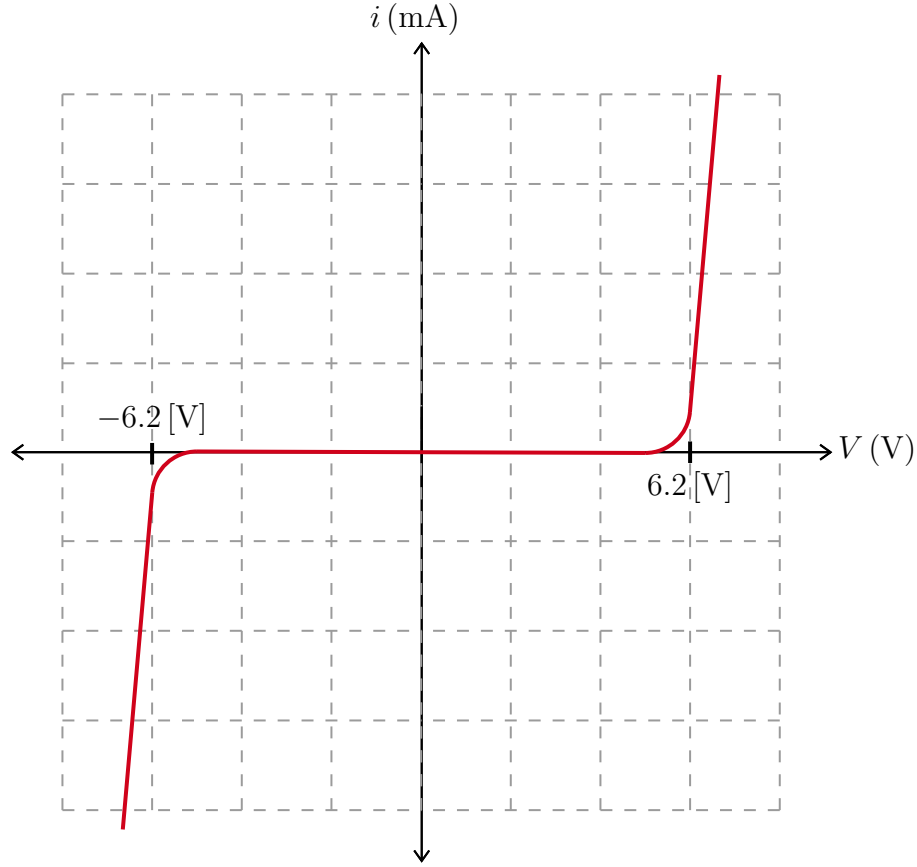
Figure 3: Plot Showing Current-Voltage Relationship for Circuit 3

2. (a) We begin assuming forward bias for both diodes, which gives a simple circuit with only resistors. This gives us a current from the source of:

$$I_s = \frac{15}{2\left(\frac{(5k)(10k)}{15k}\right)}$$

$$I_s = 2.25[\text{mA}]$$

The current then splits into the branches. We can calculate the current across the first 10k and 5k resistors as:

$$i_{5k} = \left(\frac{10}{15}\right)(2.25)$$

$$i_{10k} = \left(\frac{5}{15}\right)(2.25)$$

$$i_{5k} = 1.5[\text{mA}]$$

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$$i_{10k} = .75[\text{mA}]$$

Since there is a positive current through the branch containing D_1, we know the first diode is forward-biased (so voltage must be zero). Since the next set of parallel resistors has the same values as the first set, we know that the current flow will be the same. Thus, we can say that the current through D_2 is:

$$I + i_{5k} = i_{10k}$$
$$I = -.75[\text{mA}]$$

Since this value is less than zero, the second diode is reverse-biased. We now change our assumptions and solve for the voltages. Since there are two branches with equivalent resistances of 15k, we know that the voltage will split such that the 10k resistor receives $10[\text{V}]$ and the 5k resistor receives $5[\text{V}]$. Thus, the voltage drop across D_2 is $5[\text{V}]$ and the current through each parallel connection is $1[\text{mA}]$. The diodes may be tabulated as follows:

Diode	$V[\text{V}]$	$I[\text{mA}]$
D_1	0	1
D_2	5	0

We observe the following values: $\boxed{V = 10[\text{V}], I = 0[\text{mA}]}$

(b) If both of the diodes are forward-biased, then two voltage sources would be in parallel; since this is not feasible, one must be on while the other is off. Since the problem asks for the current through the D_1 branch, let us assume it is forward-biased, while D_2 is reverse biased. This gives:

$$I = \frac{6}{1k}$$
$$\boxed{I = 6[\text{mA}]}$$

Since the voltage is expended solely on the resistor, we estimate:

$$\boxed{V = 6[\text{V}]}$$

(c) Let use begin by assuming both diodes are forward-biased. In this case, there are 15 volts at the positive node of the 2.2k resistor, and 15 volts across the 1.5k resistor. We may observe that at the negative node, there are -15 volts. This means the voltage drop across the 2.2k resistor is $30[]$. We may solve for the current:

$$V_{2.2k} = \frac{15 - (-15)}{2.2}$$
$$V_{2.2k} = 13.636[\text{mA}]$$

The current through the 1.5k resistor may be found as well, as we know the voltage drop will be 30[V] as well:

$$V_{2.2k} = \frac{15 - (-15)}{1.5}$$

$$V_{2.2k} = 20[\text{mA}]$$

We can use this to solve for the current through D_2:

$$I = 20 + 13.636$$

$$I = 33.636[\text{mA}]$$

As such, our initial assumptions are correct, and our values of interest are:

$$\boxed{V = 30[\text{V}], \; I = 33.636[\text{mA}]}$$

3. Repeat Problem 2, but using the Constant Voltage Drop (CVD) model with a voltage drop of .7[V] for forward-biased diodes

   (a) From 2(a), we know that D_1 is forward-biased, and D_2 is reverse-biased. This means that we can calculate the current through the branch as:

   $$i = \frac{15 - .7}{15k}$$

   $$i = .9533[\text{mA}]$$

   This gives:

   $$V = (.9533)(10)$$

   $$\boxed{V = 9.533[\text{V}]}$$

   Since D_2 is still reverse-biased, the current remains $\boxed{I = 0[\text{A}]}$.

   (b) From 2(b), we know that D_1 is forward-biased, and D_2 is reverse-biased. This gives us the current as:

   $$I = \frac{6 - .7}{1k}$$

   $$\boxed{I = 5.3[\text{mA}]}$$

   The voltage is then:

   $$V = 6 - .7$$

   $$\boxed{V = 5.3[\text{V}]}$$

(c) We know that both diodes are forward-biased. This means the voltage at the positive terminal of the 2.2k resistor is:

$$V^+ = 15 - .7$$
$$V^+ = 14.3[\text{V}]$$

And at the negative node it is:

$$V^- = -15 - .7$$
$$V^- = -15.7[\text{V}]$$

Thus, the voltage drop remains the same as previously observed $\boxed{V = 30[\text{V}]}$. This means the current through both the 2.2k and the 1.5k resistor does not change, which implies the current stays the same as well:

$$\boxed{I = 33.636[\text{mA}]}$$

4. We can use the Shockley Equation to model this problem:

$$I_D = I_S \left[e^{\frac{V_D}{nV_T}} - 1 \right]$$

Since $I_D/I_S \gg 1$, we can eliminate the -1, and write:

$$\frac{I_D}{I_S} = e^{\frac{V_D}{nV_T}}$$

Furthermore, we know that, at room temperature, the thermal voltage is:

$$V_T \approx 25[\text{mA}]$$

we can now use the given equations to set up a system and solve.

(a) We begin by writing:

$$\frac{5 \cdot 10^{-6}}{I_S} = e^{\frac{.5}{.025n}}$$
$$\frac{10^{-4}}{I_S} = e^{\frac{.6}{.025n}}$$

This allows us to write:

$$10^{-4} e^{\frac{.6}{.025n}} = (5 \cdot 10^{-6}) e^{\frac{.5}{.025n}}$$
$$e^{-\frac{.6}{.025n}} = .05 e^{-\frac{.5}{.025n}}$$

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$$e^{-\frac{4}{n}} = .05$$

$$\frac{4}{n} = -\ln(.05)$$

$$n = -\frac{4}{\ln(.05)}$$

This gives us:

$$\boxed{n = 1.33}$$

(b) We can go back and solve the equations using the obtained value of the emissions coefficient:

$$I_S = 10^{-4}e^{-\frac{.6}{(1.33)(.025)}}$$

$$\boxed{I_S = 1.5625 \cdot 10^{-12}[\text{A}]}$$

We can confirm our calculation by using the first equation:

$$I_S = (5 \cdot 10^{-6})e^{-\frac{.5}{(1.33)(.025)}}$$

$$\boxed{I_S = 1.5625 \cdot 10^{-12}[\text{A}]}$$

5. We know that the sum of the voltages in the isolated loop containing the diode must sum to zero, which allows us to write:

$$9.1 - (28 \cdot 10^{-3})(5) - V_{zo} = 0$$

$$9.1 - .14 - V_{zo} = 0$$

$$\boxed{V_{zo} = 8.96[\text{V}]}$$

From here, we can apply the 10[mA] test case:

$$V_z = .01(5) + 8.96$$

$$\boxed{V_{z10[\text{mA}]} = 9.01[\text{V}]}$$

And finally the 100[mA] case:

$$V_z = .1(5) + 8.96$$

$$\boxed{V_{z100[\text{mA}]} = 9.46[\text{V}]}$$

6. (a) Using $V_1 = 1.5[\text{V}]$, we may begin solving by removing the voltage drop resulting from D_1:

$$V_2 = (1.5 - .7)[\text{V}]$$
$$\boxed{V_2 = .8[\text{V}]}$$

For D_3 and D_4 to be forward biased, we need a minimum voltage of $2(.7) = 1.4[\text{V}]$. Since $.8 < 1.4$, D_3 and D_4 are both reverse-biased, which results in a voltage of $\boxed{V_{out} = 0[\text{V}]}$. Although not required, we can solve for V_3, since we know there will be a $.7[\text{V}]$ drop at D_2:

$$V_{R1} = .8 - .7$$
$$V_{R1} = .1[\text{V}]$$
$$V_3 = V_2 - V_{R1}$$
$$\boxed{V_3 = .7[\text{V}]}$$

(b)

(c)