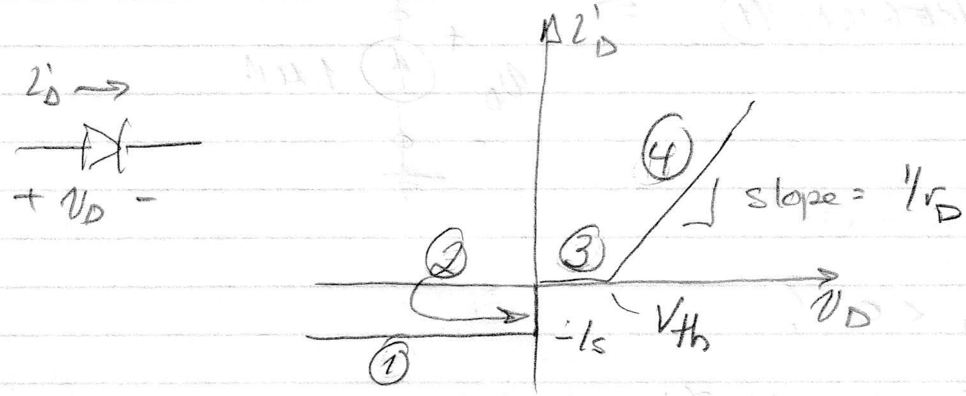
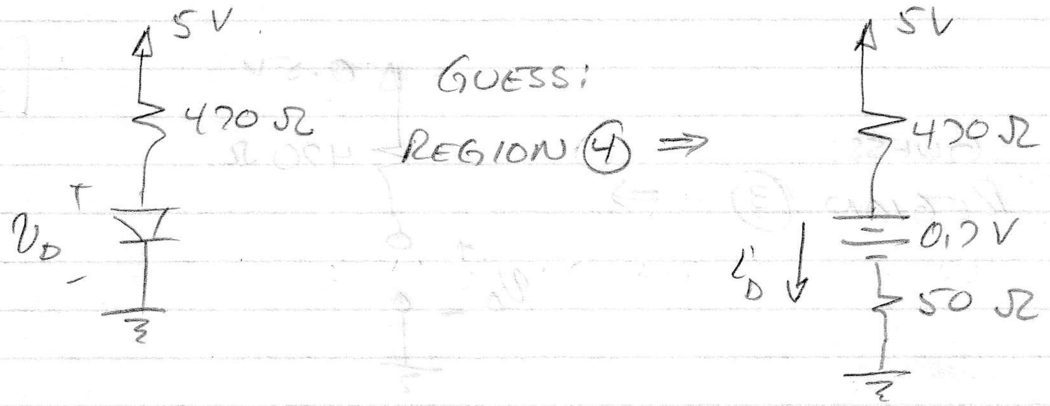
Examples: Full piece-wise linear model

$I_S = 10^{-6}$ A $\qquad r_D = 50\ \Omega \qquad V_{th} = 0.7$ V

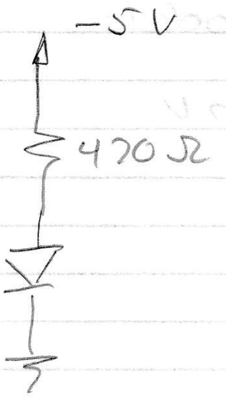


The following examples cover all four regions labelled on the plot.

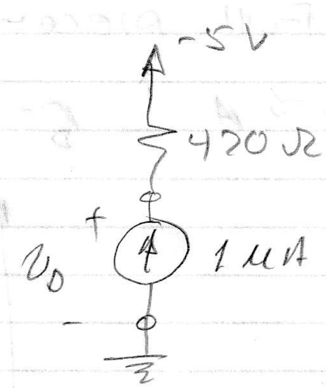


TEST: $i_D \geq 0$?

$$i_D = \frac{5-0.7}{520} = 8.3\text{ mA} \quad ✓ \quad \text{OK.}$$



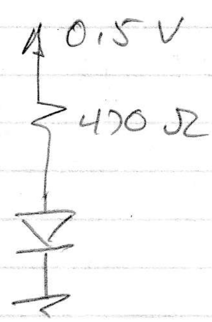
GUESS:
REGION ① ⇒



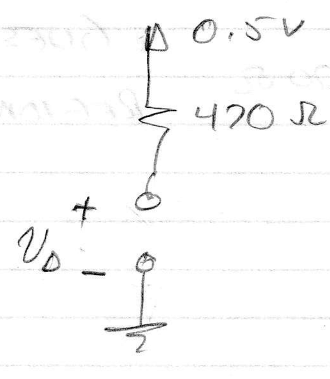
TEST: $v_D < 0$?

KVL: $5 - 470(10^{-6}) + v_D = 0$

$v_D \approx -5$ V ✓ OK



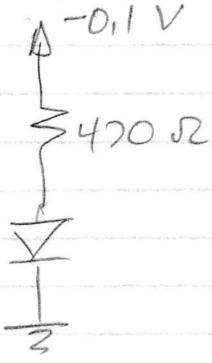
GUESS:
REGION ③ ⇒



The power supply (0.5 V) is positive but not sufficient to turn the device on, so we guess region ②.

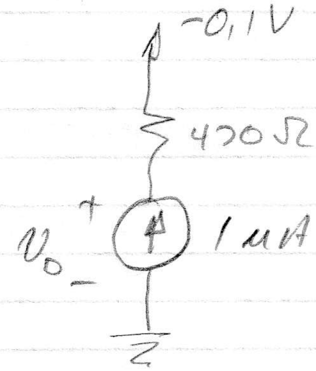
TEST: $0 \le v_D \le 0.7$ V ?

$v_D = 0.5$ V ✓ OK.



GUESS:
REGION ①

⇒

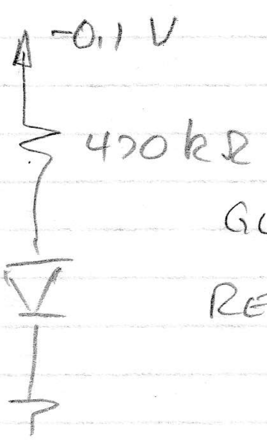


TEST: $v_D \le 0$?

$$+0.1 - 420(10^{-6}) + v_D = 0$$

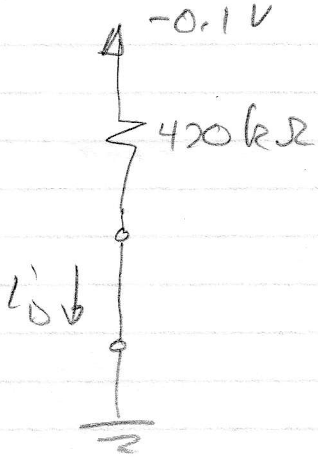
$$v_D \cong -0.1\ \text{V} \quad ✓ \quad \text{OK}$$

If the resistor is large, we might find the diode in region 2:



GUESS:
REGION ②

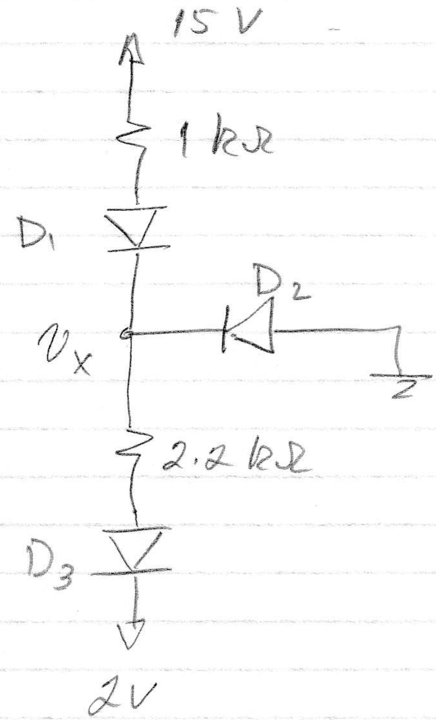
⇒



TEST: $0 \ge i_D \ge -1.0 \times 10^{-6}\ \text{A}$?

$$i_D = \frac{-0.1}{420\ \text{k}} = -0.213\ \mu\text{A} \quad ✓ \quad \text{OK.}$$

Example: $I_s = 100\ \mu A$ $\quad r = 50\ \Omega$ $\quad V_{Th} = 0.7\ V$



It would appear that

$D_1 \rightarrow$ ON

If v_X is more than 2.7 V, D_3 will be ON, and D_2 will be OFF.

Let's try that...

$$0 = \frac{v_X - 15 + 0.7}{1050} + \frac{v_X - 2 - 0.7}{2250} + 10^{-4}$$

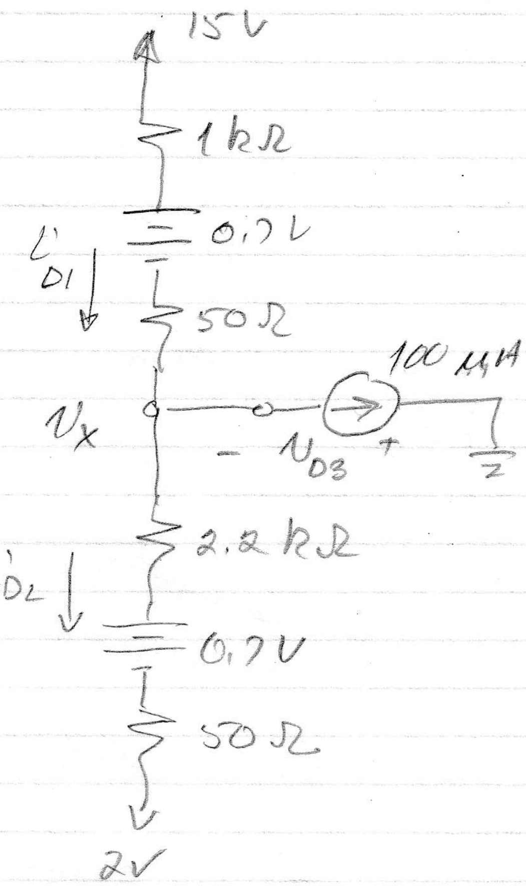
$$\Rightarrow v_X = 10.54\ V$$

$$i_{D1} = \frac{15 - v_X - 0.7}{1050} = 3.58\ mA \checkmark$$

$$i_{D2} = \frac{v_X - 2 - 0.7}{2250} = 3.48\ mA \checkmark$$

$$-v_{D3} = 2250\, i_{D2} + 0.7$$

$$v_{D3} = -8.53\ V \checkmark$$

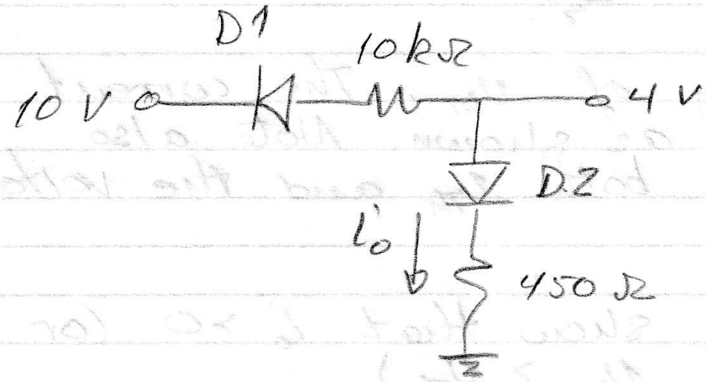


GOOD ASSUMPTION!

Example using Piece-wise Linear model
(based on Quiz 3 Spring 2000)

Use the linear piecewised diode model with $v_{Th} = 0.6\ V$, $r = 50\ \Omega$, and $I_S = 1\ mA$ to i_o in the circuit below.

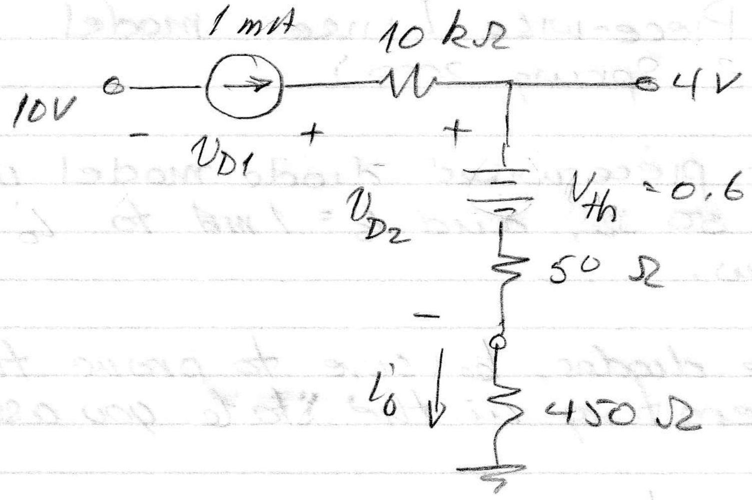
For each of the diodes be sure to prove that the diode is operating in the state you assume.



Because of the +4 V source, we will guess that D2 is ON, and in the forward bias ($v_D > v_{Th}$) region.

Because the 10 V source is in a position to put D1 in reverse bias, we will assume it is OFF, with $v_D < 0$.

Re-drawing with appropriate diode models, we have ...



NOTE the polarity of v_{D1}. The current source is positive as shown. Note also that v_{D2} includes both v_{Th} and the voltage across r.

TEST We need to show that $i_0 > 0$ (or equivalently that $v_{D2} > v_{Th}$).

$$i_0 = \frac{4 - 0.6}{500} = 6.8 \ mA \quad ✓$$

So this is OK

TEST We need to show that v_{D1} is negative.

KVL $\quad -10 - v_{D1} + 10^{-3}(10\,000) + 4 = 0$

$$\therefore \quad v_{D1} = -6 + 10 = +4 \ V \quad X$$

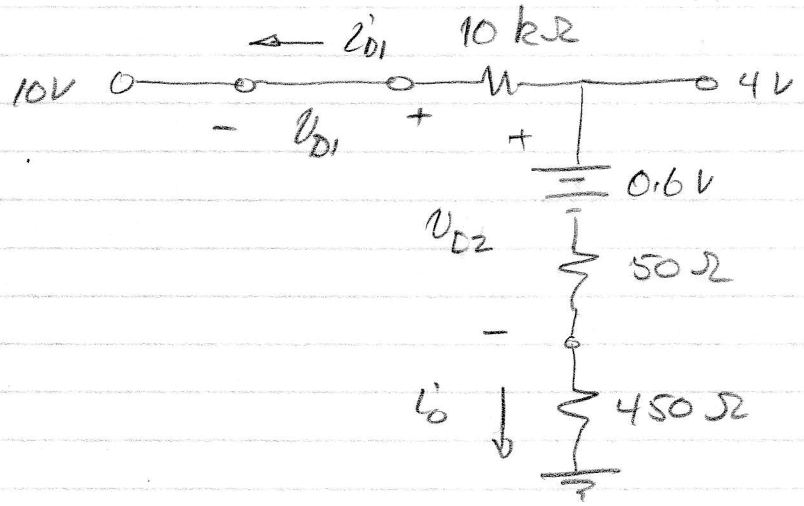
No GOOD! This is a contradiction since $v_{D1} = 4$ V suggests forward bias. So we need another guess.

So now what? It seems clear that D1 cannot be forward biased (because of the 10 V source) so we have two possibilities:

$i'_{D1} = 0 \qquad 0 \le v_{D1} \le V_{th}$ (region 3)

OR $\qquad -I_s \le i'_{D1} \le 0 \qquad v_{D1} = 0$ (region 2)

Let's choose region 2 (it looks easier to test!):



Note that i'_o has not changed, so we don't need to fuss with D2. Now

$$i'_{D1} = \frac{4-10}{10\,k} = -0.6\ mA$$

So this is GOOD! we have

$v_{D1} = 0 \qquad -1\,mA \le i'_{D1} \le 0$

which is region 2.