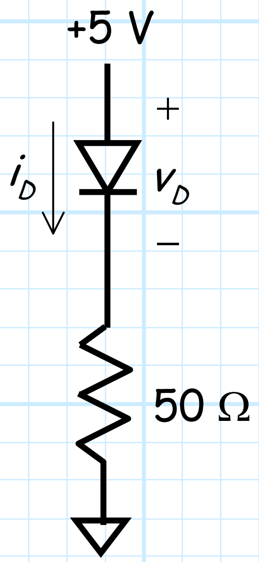
Example: Junction Diode Models

Consider the **junction** diode circuit, where the junction diode has device parameters $I_S = 10^{-12}$ A, and $n = 1$:



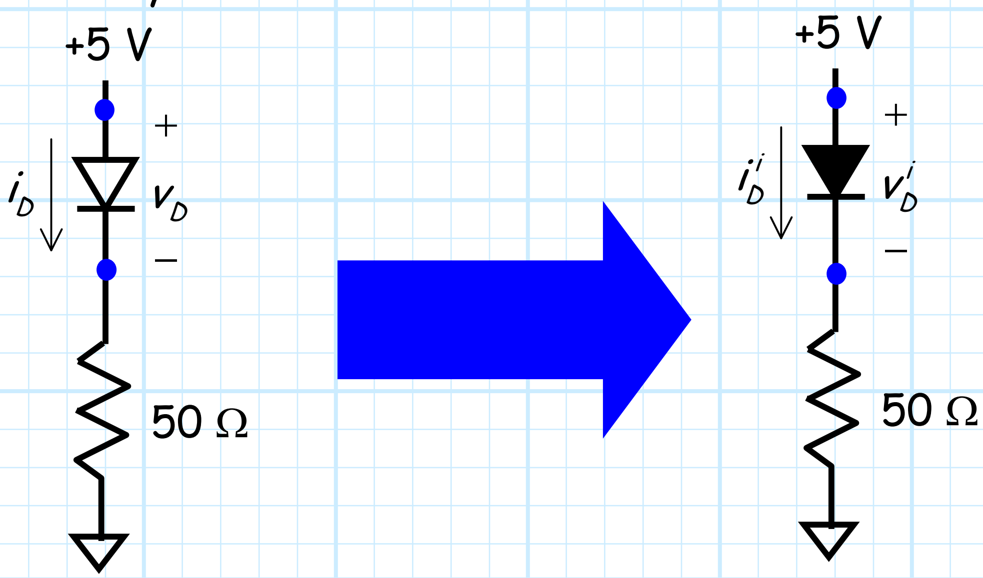
I **numerically** solved the resulting transcendental equation, and determined the **exact** solution:

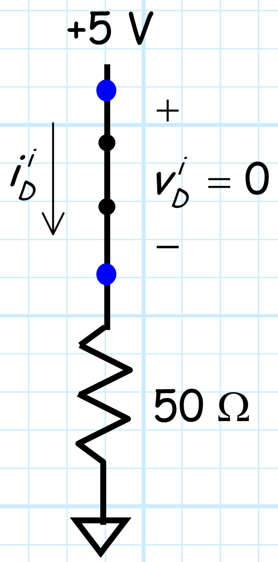
$$i_D = 87.40 \ mA$$

$$v_D = 0.630 \ V$$

Now, let's determine **approximate** values using diode **models** !

First, let's try the **ideal diode model**.





Assume **IDEAL** diode is "on".

Enforce $v_D^i = 0$.

Analyze the **IDEAL** diode circuit.
From KVL:

$$= 0$$

$$\therefore \; i_D^i =$$

Check result:

We therefore can **approximate** the **junction diode** current as the current through the ideal diode **model**:

$$i_D \approx i_D^i = 100 \text{ mA}$$

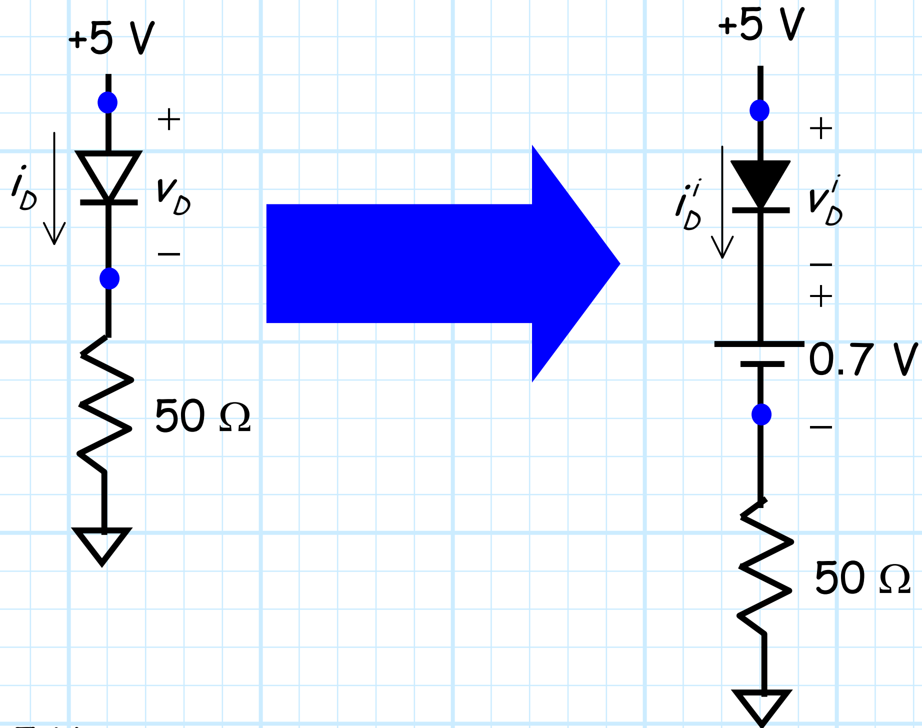
And **approximate** the **junction** diode voltage as the voltage across the ideal diode **model**:

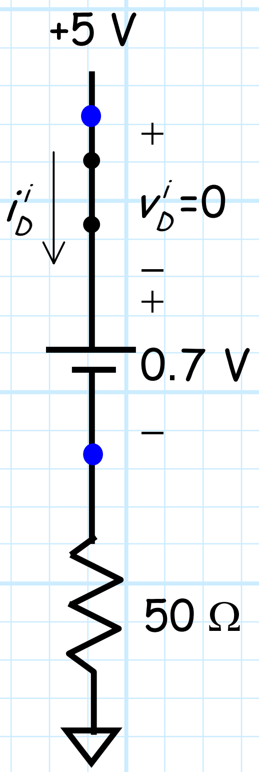
$$v_D \approx v_D^i = 0$$

Compare these approximations to the **exact** solutions:

$$i_D = 87.4 \; mA \quad \text{and} \quad v_D = 0.630 \text{ V}$$

Close, but we can do better! Let's use the **CVD model**.





<u>Assume</u> **IDEAL** diode is "on".

<u>Enforce</u> $v_D^i = 0$.

<u>Analyze</u> the **IDEAL** diode circuit. From KVL:

$$= 0$$

$$\therefore \; i_D^i =$$

<u>Check</u> the result:

We therefore can **approximate** the **junction** diode current as the current through the CVD **model**:

$$i_D \approx i_D^i = 86.0 \; mA$$

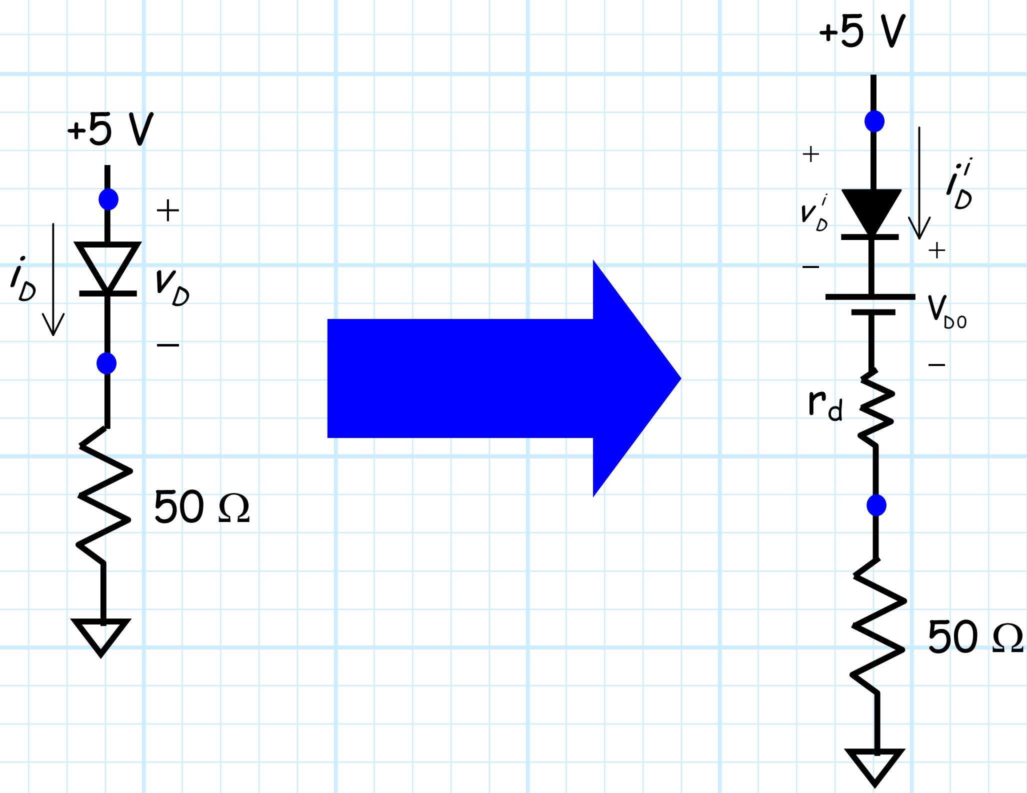
And **approximate** the **junction** diode voltage as the voltage across the CVD **model**:

$$\begin{aligned} v_D &\approx v_D^i + 0.7 \\ &= 0.0 + 0.7 \\ &= 0.7 \; V \end{aligned}$$

Compare these approximations to the **exact** solutions:

$$i_D = 87.4 \text{ mA} \qquad \text{and} \qquad v_D = 0.630 \text{ V}$$

Much better than before, but we can do even better! Let's use the **PWL model**.



Q: *But, what* ***values*** *should we use for model parameters V_{D0} and r_d ??*

A: From the CVD model, we know that i_D is approximately 86mA. Therefore, let's create a **PWL model** that is accurate in the region between, say, 50 mA < i_D < 125 mA.

First, we determine v_D at 50 mA and 125 mA.

$$\begin{aligned} v_D &= nV_T \ln(i_D/I_S) \\ &= \\ &= \end{aligned}$$

We now know two points lying on the junction diode curve! Let's construct a PWL model whose "line" **intersects** these two points.

Recall that when the ideal diode is forward biased, applying KVL to the PWL model results in:

$$v_D = V_{D0} + i_D r_d$$

or equivalently:

$$i_D = \frac{v_D}{r_d} - \frac{V_{D0}}{r_d}$$

Inserting the junction diode values into this PWL model equation provides:

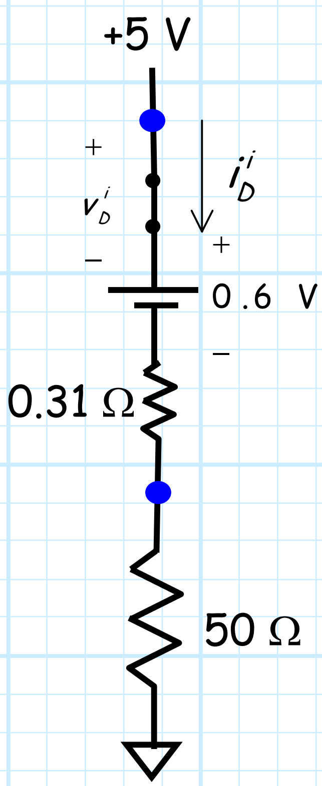
$$0.616 = V_{D0} + (0.05)r_d$$

$$0.639 = V_{D0} + (0.125)r_d$$

Two equations and **two** unknowns !! Solving, we get:

V_{D0} = 0.600 V and r_d = 0.31 Ω (small !!)

Therefore, the ideal diode circuit is:



Assume the **IDEAL** diode is "on".

Enforce $v_D^i = 0$.

Analyze the **IDEAL** diode circuit. From KVL:

$$= 0$$

$$\therefore \; i_D^i =$$

Check the result:

We can therefore **approximate** the **junction** diode current as the current through the PWL **model**:

$$i_D \approx i_D^i = 87.5 \ mA$$

and **approximate** the **junction** diode voltage as the voltage across the PWL model:

$$\begin{aligned} v_D &= v_D^i + V_{D0} + i_D^i \ r_D \\ &= 0 + 0.600 + (0.087)0.31 \\ &= 0.627 \ V \end{aligned}$$

Now, compare these values to the **exact** values v_D = 0.630 V and i_D= 87.4 mA.

The **error** of the PWL model estimates is just 0.003 Volts and 0.1 mA !

Each model provides **better** estimates than the previous one!