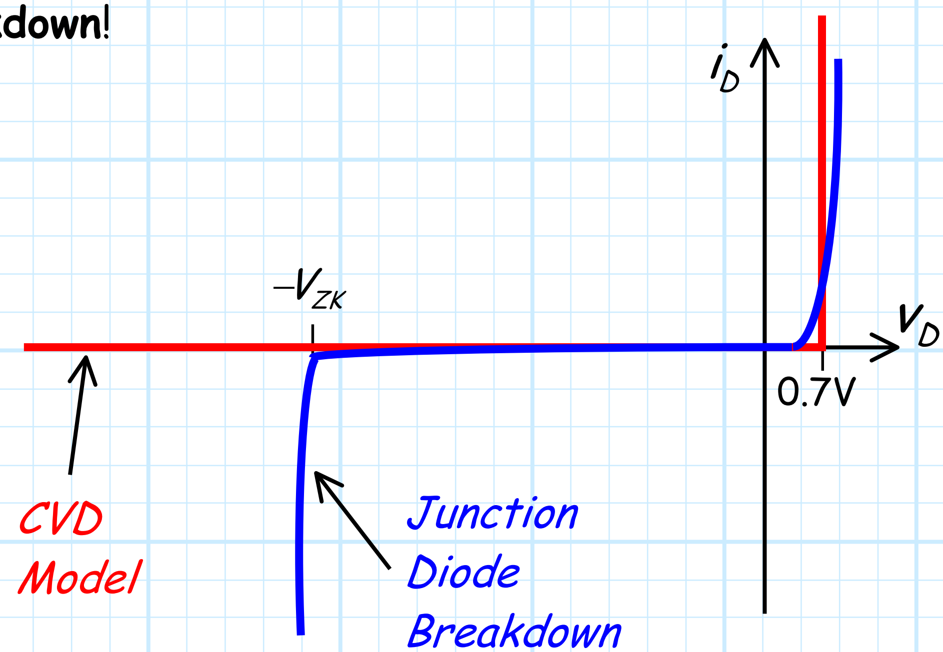
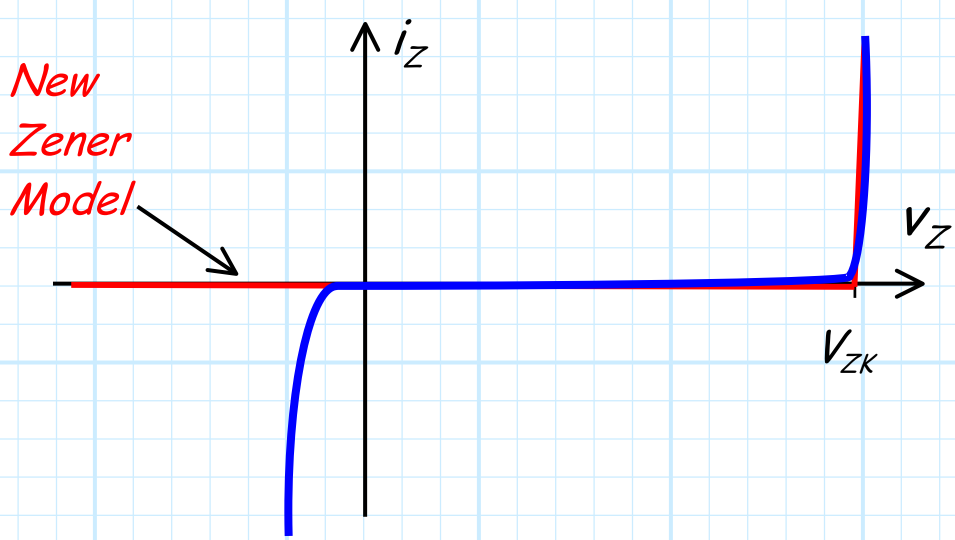
Zener Diode Models

The conventional diode models we studied earlier were based on junction diode behavior in the **forward** and **reverse** bias regions—they did **not** "match" the junction diode behavior in **breakdown**!



However, we assume that **Zener** diodes most often operate in **breakdown**—we need **new** diode models!

Specifically, we need models that match junction/Zener diode behavior in the **reverse bias** and **breakdown** regions.



We will study **two** important zener diode models, each with **familiar** names!

1. The Constant Voltage Drop (CVD) Zener Model
2. The Piece-Wise Linear (PWL) Zener Model

The Zener CVD Model

Let's see, we know that a Zener Diode in **reverse** bias can be described as:

$$i_Z \approx I_s \approx 0 \quad \text{and} \quad v_Z < V_{ZK}$$

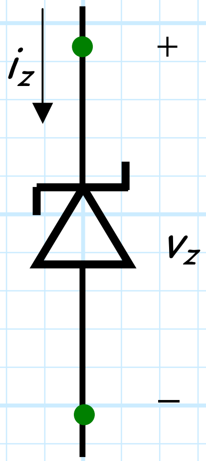
Whereas a Zener in **breakdown** is approximately stated as:

$$i_Z > 0 \quad \text{and} \quad v_Z \approx V_{ZK}$$

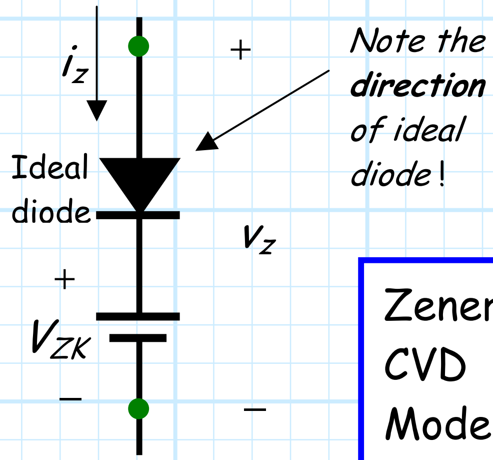
Q: *Can we construct a **model** which behaves in a **similar** manner??*

A: Yes! The **Zener CVD model** behaves precisely in this way!

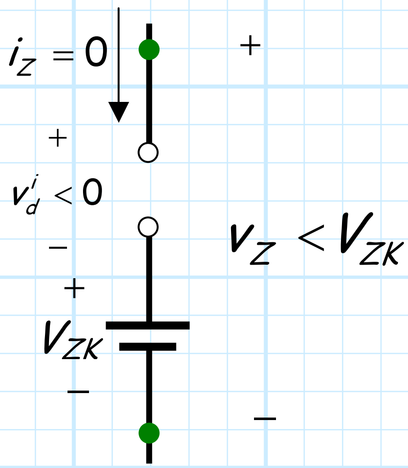
Replace:



with:



Zener CVD Model



Analyzing this Zener CVD model, we find that **if** the model voltage v_Z is less than V_{ZK} (i.e., $v_Z < V_{ZK}$), then the **ideal** diode will be in **reverse** bias, and thus the model current i_Z will equal **zero**. In other words:

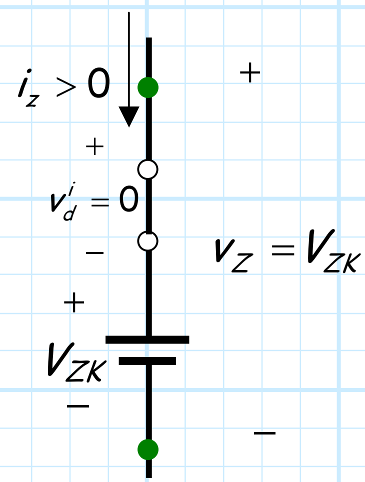
$$i_Z = 0 \quad \text{and} \quad v_Z < V_{ZK}$$

Just like a **Zener** diode in **reverse bias**!

Likewise, we find that **if** the model current is positive (i_Z>0), then the **ideal** diode must be **forward** biased, and thus the model voltage must be $v_Z = V_{ZK}$. In other words:

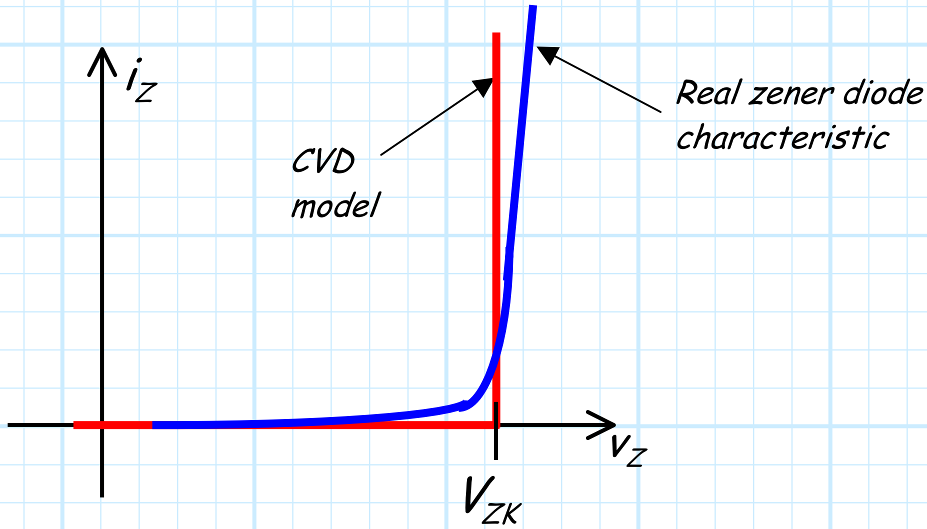
$$i_Z > 0 \quad \text{and} \quad v_Z = V_{ZK}$$

Just like a **Zener** diode in **breakdown**!



Problem: The voltage across a zener diode in breakdown is NOT EXACTLY equal to V_{ZK} for all $i_z > 0$. The CVD is an **approximation**.

In **reality**, v_Z **increases** a very small (tiny) amount as i_Z increases.

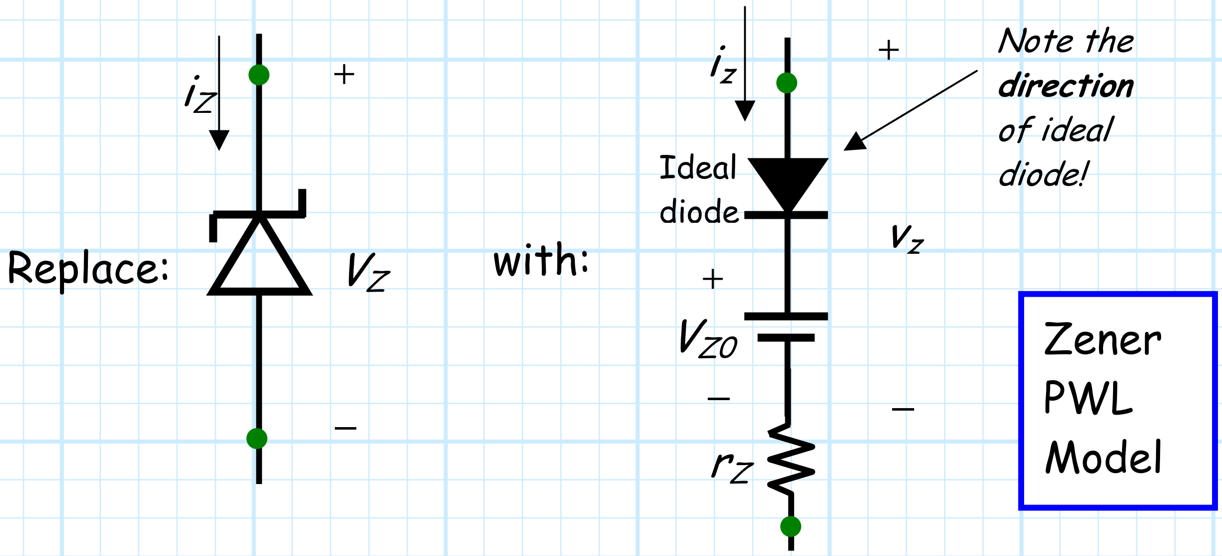


Thus, the CVD model causes a **small** error, usually acceptable—but for some cases **not**!

For these cases, we require a **better** model:

→ The Zener (PWL) Piece-Wise Linear model.

The Zener Piecewise Linear Model

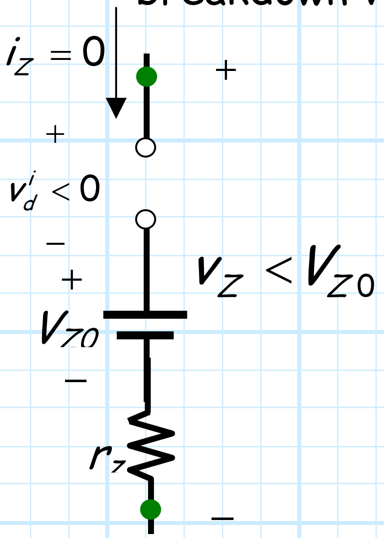


Please Note:

* The PWL model includes a **very small** series resistor, such that the voltage across the model v_z **increases slightly** with increasing i_z .

* This small resistance r_Z is called the **dynamic resistance**.

* The voltage source V_{Z0} is **not** equal to the zener breakdown voltage V_{ZK}, however, it is typically **very close**!



Analyzing this Zener PWL model, we find that **if** the model voltage v_Z is less than V_{Z0} (i.e., $v_Z < V_{Z0}$), then the **ideal** diode will be in **reverse** bias, and the model current i_Z will equal zero. In other words:

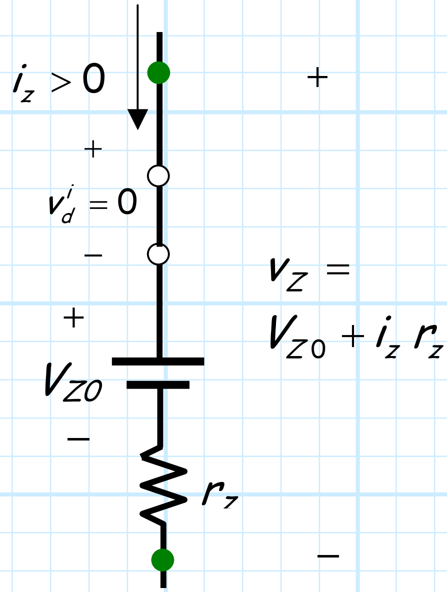
$i_Z = 0$ and $v_Z < V_{Z0} \approx V_{ZK}$

Just like a **Zener** diode in **reverse bias**!

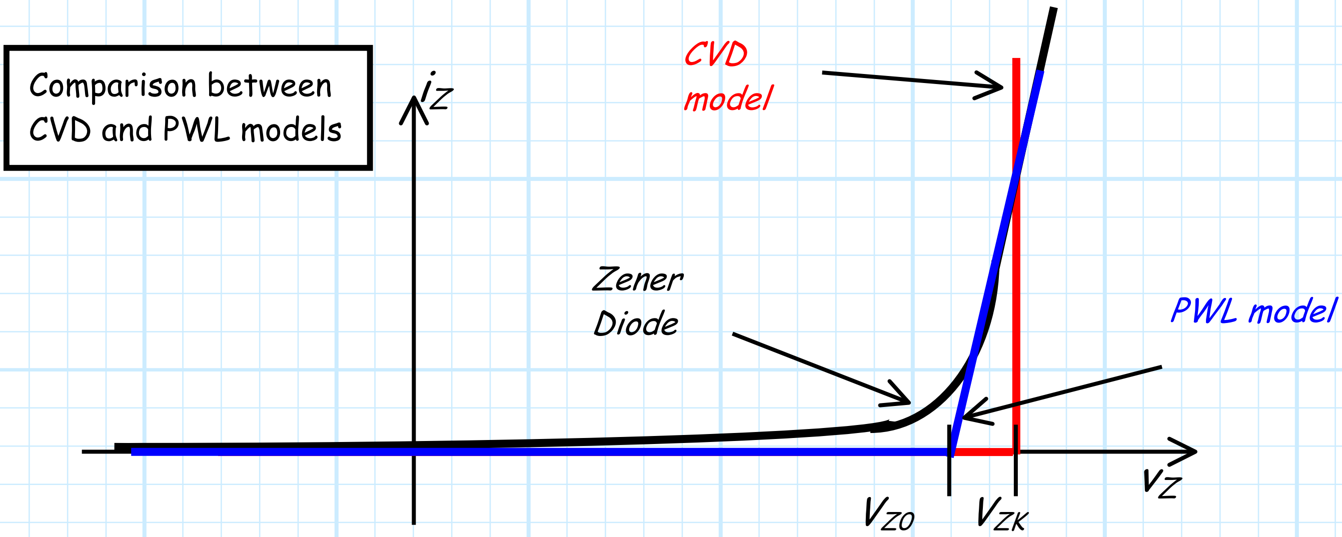
Likewise, we find that **if** the model current is positive ($i_Z > 0$), then the **ideal** diode must be **forward** biased, and thus:

$i_Z > 0$ and $v_Z = V_{Z0} + i_Z r_Z$

Note that the model voltage v_Z will be near V_{ZK}, but will increase **slightly** as the model current increases.

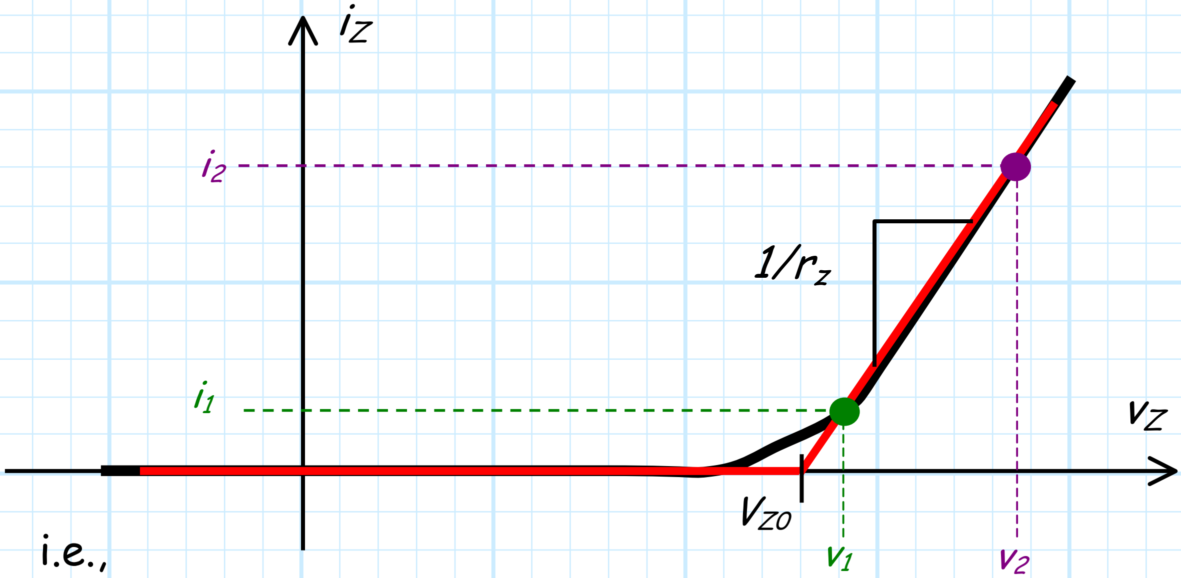


Just like a **Zener** diode in **breakdown**!



Q: *How do we **construct** this PWL model (i.e., find V_{Z0} and r_z)?*

A: Pick **two points** on the zener diode curve (v_1, i_1) and (v_2, i_2), and then select r_z and V_{Z0} so that the PWL model line **intersects** them.



i.e.,

$$r_z = \frac{v_2 - v_1}{i_2 - i_1}$$

and

$$V_{z0} = v_1 - i_1 r_z \qquad \text{or} \qquad V_{z0} = v_2 - i_2 r_z$$