4.1 The Ideal Diode

Reading Assignment: pp.165-172

Before we get started with ideal diodes, let's first recall **linear device behavior**!

HO: LINEAR DEVICE BEHAVIOR

Now, the **ideal diode** is our first "**electronic**" circuit device. It is **asymmetric**, and **non-linear**.

Q: *Is it also made from* ***semi-conductors****?*

A: Actually, **ideal** diodes are entirely made from our **imaginations**!

HO: THE IDEAL DIODE

Q: *I see the* ***math****, and I see the* ***plots****, but I'm still* ***not sure*** *what an ideal diode actually* ***does****.*

A: Perhaps an **analogy** would help!

HO: DIODE MECHANICAL ANALOGY

Q: *So we can use these things in **circuits**?*

A: Sure! But we will find **analyzing** the circuit is **problematic**.

HO: IDEAL DIODE CIRCUITS

Q: *So just how **do** we analyze ideal diode circuits?*

A: Just **carefully** and **precisely** and **patiently** follow the **steps** delineated in "Ideal Diode Circuit Analysis Guide"

HO: THE IDEAL DIODE CIRCUIT ANALYSIS GUIDE

Q: *Can you give us a few **examples** to help illustrate this procedure?*

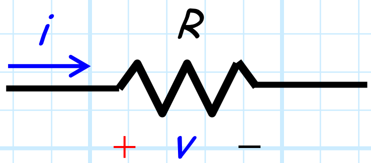
A:

EXAMPLE: A SIMPLE IDEAL DIODE CIRCUIT

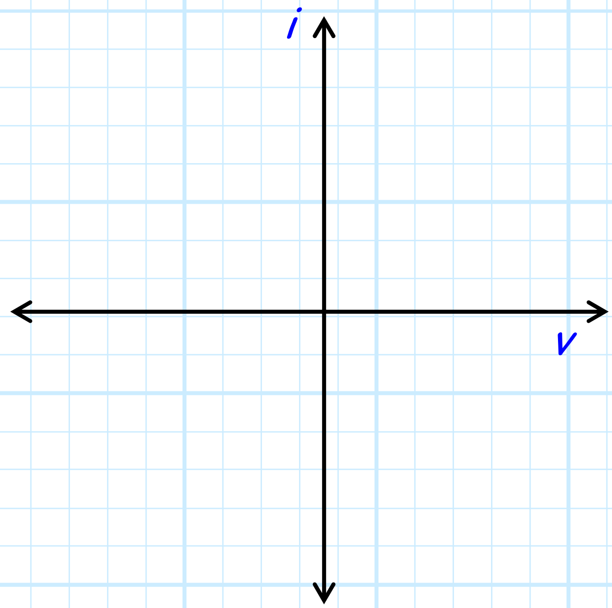
EXAMPLE: ANALYSIS OF A COMPLEX IDEAL DIODE CIRCUIT

Linear Device Behavior

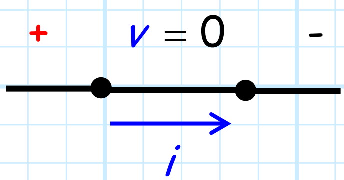
1) Recall the circuit behavior of a **resistor**:



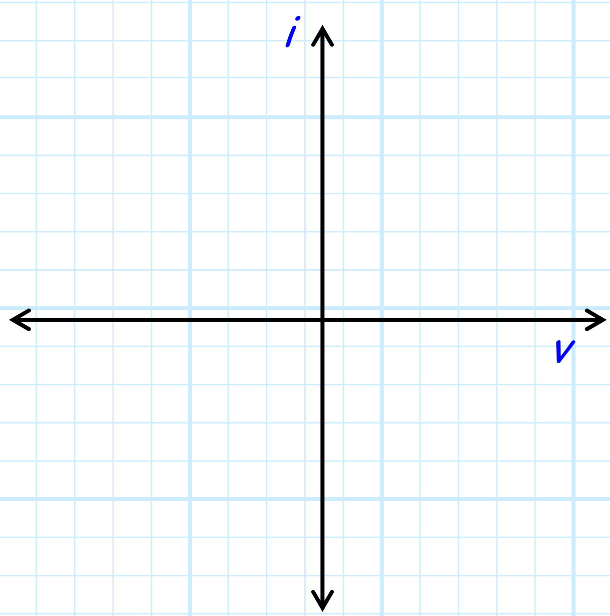
$$i = \frac{v}{R}$$



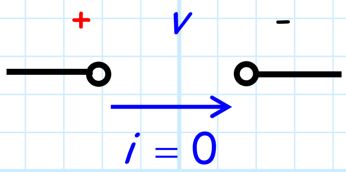
2) If $R = 0$, then we have a **short** circuit:

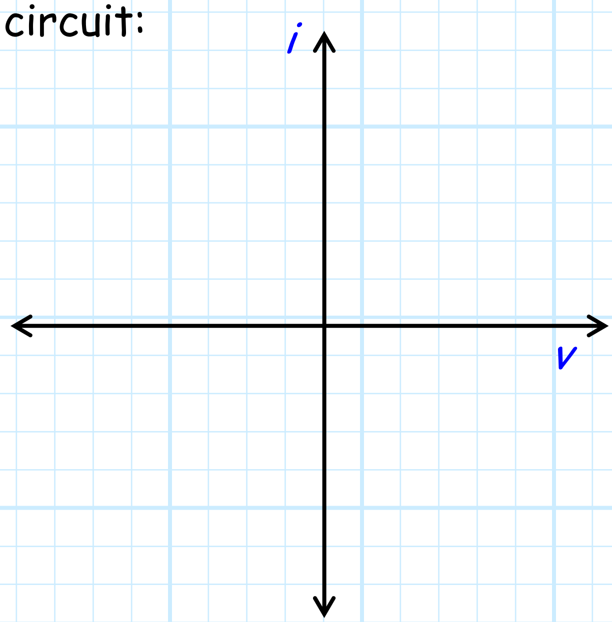


$$v = 0$$



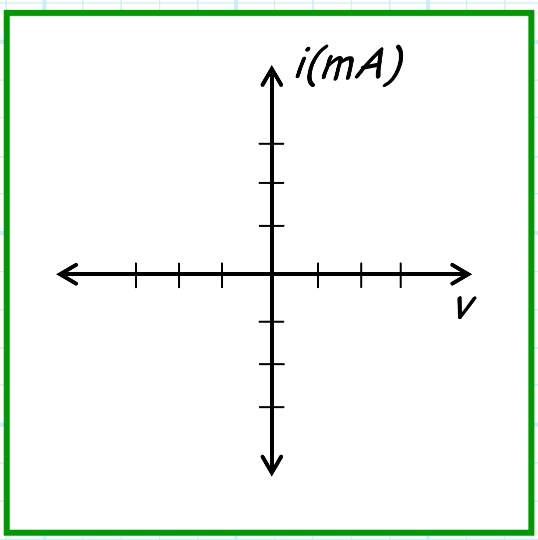
3) If R=∞ , then we have a **open** circuit:

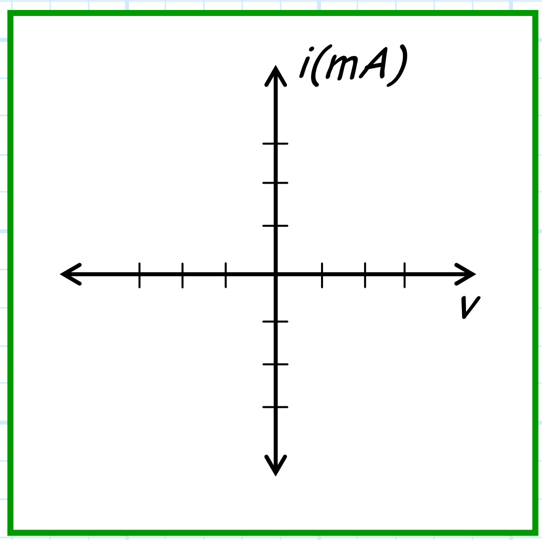


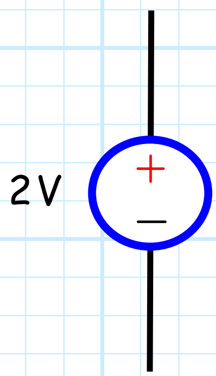


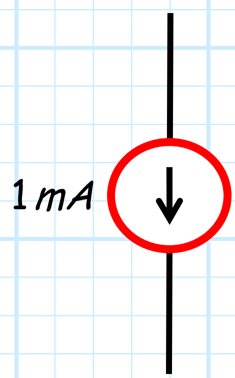
$i = 0$

4) We can also plot the behavior of both current and voltage **sources**:









The Ideal Diode

Diodes are perhaps the most **fundamental** of all **non-linear** circuit elements.

* Like a resistor, inductor, or capacitor, a diode is a **two-terminal** device.

* Thus, its behavior is characterized by the **relationship** between the **current** through the device, and the **voltage** across it.

* Unlike **linear** two-terminal devices, the relationship between **diode** voltage and **diode** current is a little **complicated**!

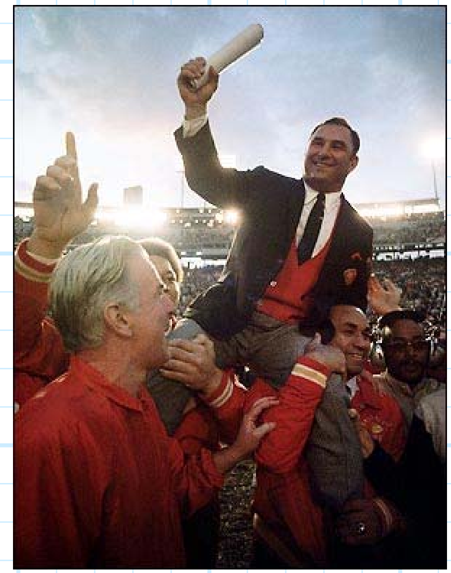
To begin, we consider the **ideal diode**.

As the name implies, this device is **ideally** how a diode would behave—**if** we knew how to actually build an ideal diode.

Unicorns and leprechauns are more likely

Q: *You mean we're going to study a device that* ***doesn't really exist****? What's the point in* ***that****?*

A: Like **unicorns** or **leprechauns** or Kansas City Chiefs' **playoff victories**, ideal diodes are **mythical**—they only exist in our **mind**.

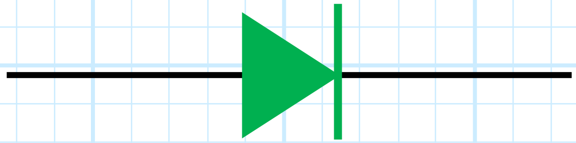


However, studying these **imaginary devices** is important and useful, as we will **acquire skills** necessary to understand and analyze **junction diodes**.

Junction diodes we **can** build—they **do** exist—and in many ways they behave **similarly** to ideal diodes.

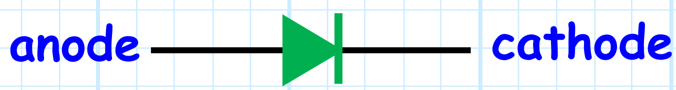
It's green like a leprechaun

So first, the **ideal diode circuit symbol**:



Note that it is **asymmetric**—it has an **"A" side** and a **"B" side**!

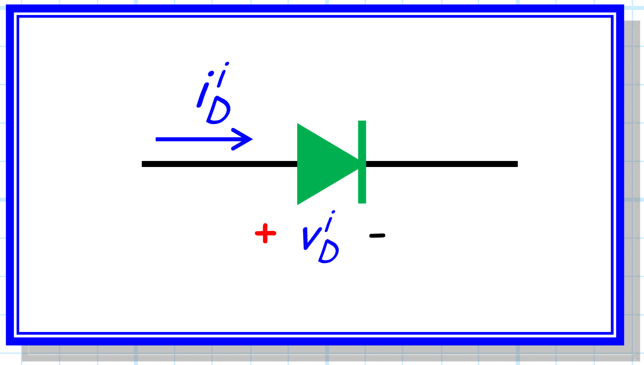
One terminal is called the **anode**, and the other is called the **cathode**.



Resolve to commit this to **memory**!

The standard ideal diode notation

With respect to the **current through** and **voltage across** this device, the **standard notation** is:



Thus, we can conclude:

1. Ideal diode current i_D' is **positive, if** flowing **from the anode**, **to the cathode**.

2. Ideal diode voltage v_D' is **positive, if** the **anode** potential is **greater** than the **cathode** potential.

Resolve to commit **this** to memory as well!

It's complicated in a complicated way

Q: *So, what's the **relationship** between ideal diode **voltage** v_D^i and ideal diode **current** i_D^i?*

A: It's a little **complicated**.

Q: *I see, since an ideal diode is a **non-linear** device, the ideal diode voltage and ideal diode current is **probably** related by some **crazy** non-linear function, like:*

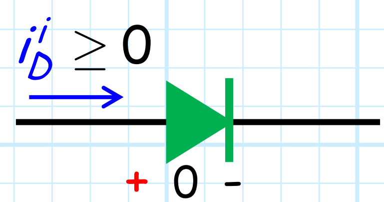
$$i_D^i = \sqrt{\pi\left(v_D^i\right)^2 - 62.3\left(v_D^i\right)^3 + e^{v_D^i}}$$

Right?

A: It's **not** complicated like **that**; it's complicated in a **different** sort of way.

Q: *????*

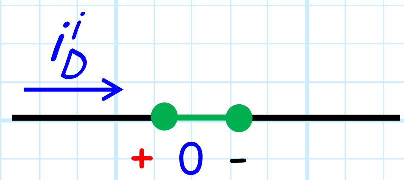
A: For an **ideal diode**, we find that **if** current is flowing from the anode to the cathode (i.e., $i_D^i \geq 0$), then the voltage across the ideal diode is **zero**(i.e., $v_D^i = 0$)— **regardless** of how much positive current is flowing:



See what I mean?

Q: *Hey! That's not complicated **at all**!*

*The voltage across it is **zero**, **regardless** of the current flowing through it—that describes a **short circuit**:*



Right?

A: Not exactly.

For the **voltage** across an **ideal** diode to be **zero**, the current through the ideal diode **must be positive**.

Current **must** be flowing **from** the anode **to** the cathode.

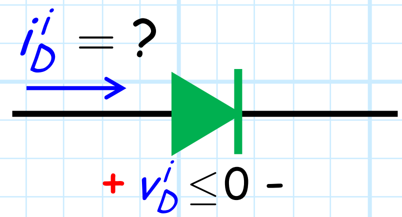
Q: *What happens if the ideal diode **current** is **negative**? What happens **if** it flows from cathode to anode?*

A: Ideal diode current **can't be negative**—it **cannot** flow from cathode to anode!

The adjective is enigmatic

Q: ***Sure** it can!*

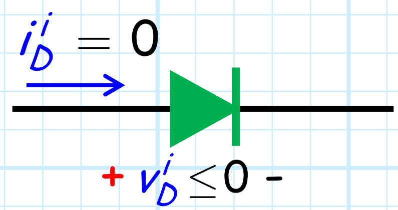
*Put a **negative voltage** across the ideal diode—make the cathode potential higher than the anode potential—and I'll bet you get a **bunch** of current flowing from cathode to anode.*

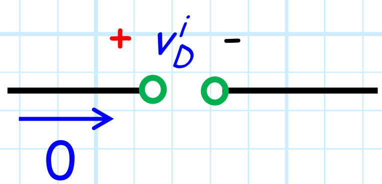


Right?

A: Wrong!

It turns out, if we place a **negative voltage—any** negative voltage—across an ideal diode (i.e., $v_D^i \leq 0$), then **no current** will flow through the diode (i.e., $i_D^i = 0$):





Q: *What the heck? This now sounds like an **open circuit**—the **current** through it is **zero**, regardless of the voltage across it.*

A: Yes, but an ideal diode behaves as an **open** circuit **only** when the **voltage** across it is **negative**.

It's a wonderful device

So, an **ideal diode** "sort of" behaves like a **short**-circuit, and it also "sort of" behaves like an **open**-circuit.

Q: *Look, I don't know how you know these things, but if you know the device equation for this goofy component, you'll tell me.*

Tell me Clarence; please, tell me!

A: You're **not** going to like it.

There are **two** equations—and they're both **conditional**:

$$i_D' = 0 \quad \text{if} \quad v_D' \leq 0$$

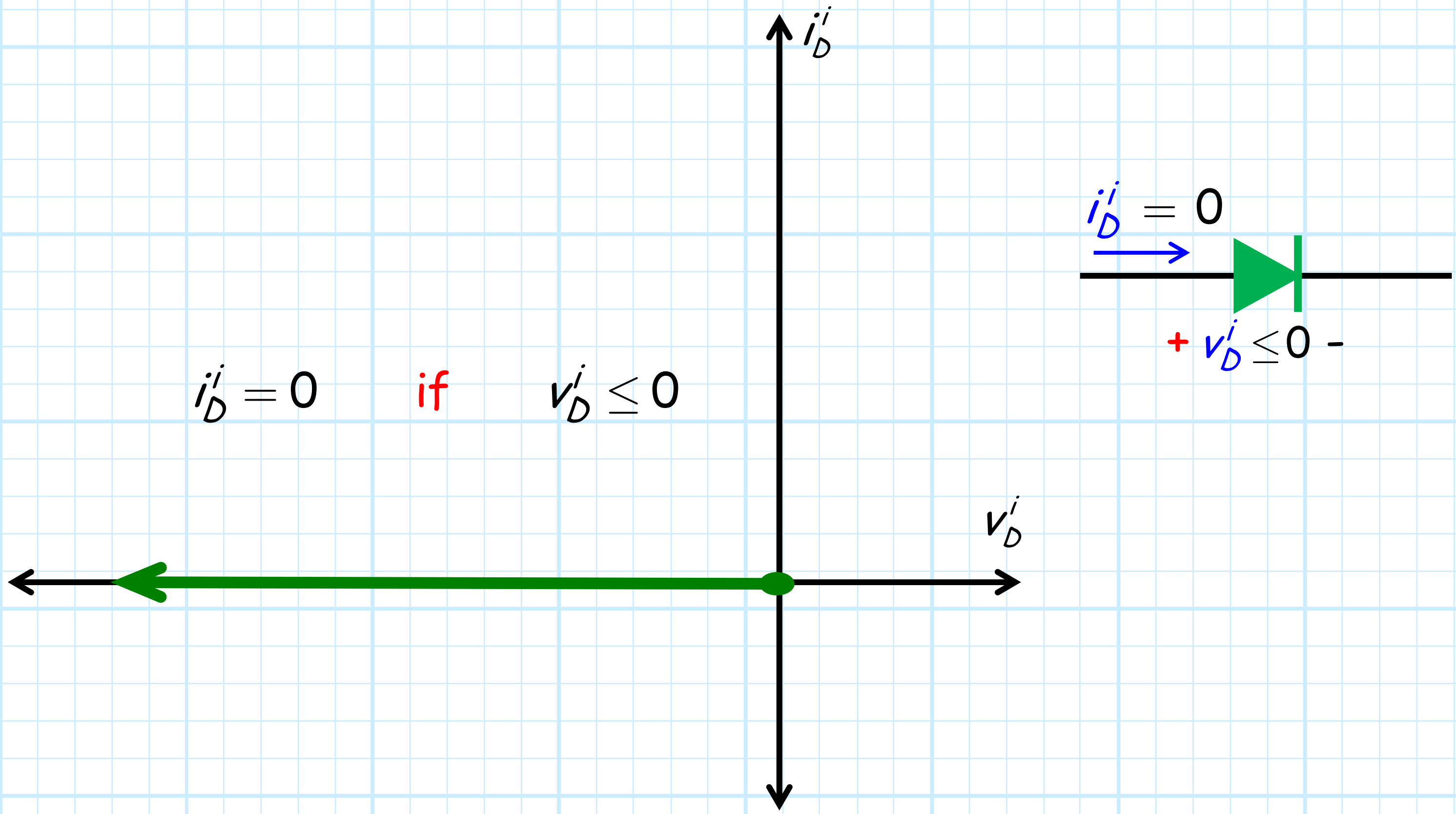
$$v_D' = 0 \quad \text{if} \quad i_D' \geq 0$$

Both equations are necessary to fully describe an ideal diode—the two equations are **not inconsistent**, nor are they in **conflict**.

Plots are always helpful

Perhaps the **best way** to see this is to **plot** the expressions.

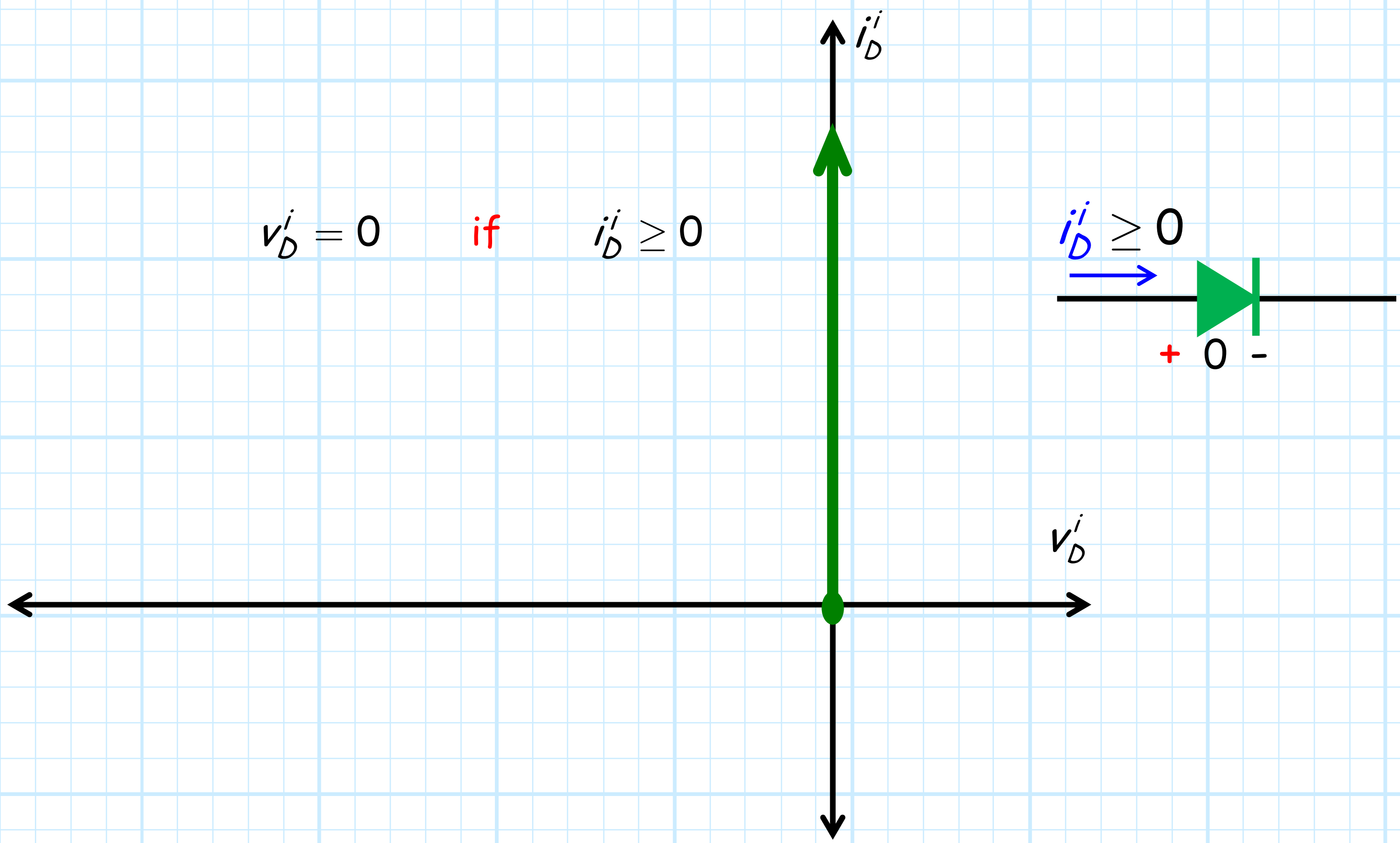
The first conditional equation looks like **one-half** of the **open-circuit** "curve"



Half-a-short

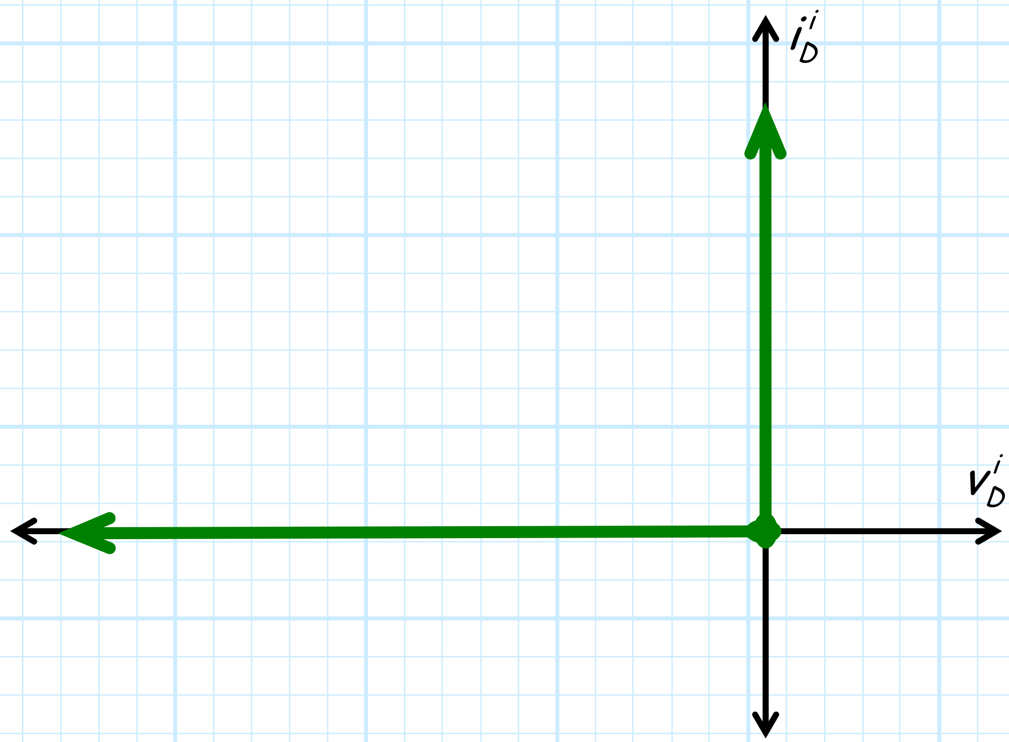
The second conditional equation looks like **one-half** of the **short-circuit** "curve":

$v_D^i = 0 \quad \text{if} \quad i_D^i \geq 0$



At least it's continuous

Together, we see the plot for the **ideal diode** to be a **continuous** one:



The values of ideal diode **current** i_D^i and ideal diode **voltage** v_D^i **must** be represented by a point **on** this green "curve".

Thus, the ideal diode **voltage** can **never be positive**, and the ideal diode **current** can **never be negative**!

Because I said so

Q: *Why **can't** they be? Why can't I place a **positive voltage** across an ideal diode? Why can't I put a **negative current** through an ideal diode?*

A: For the same reason you can't place a **positive voltage** across a **short circuit**, or a **negative current** through an **open circuit**!

Q: *So how do we **deal** with these **two conditional device equations**?*

A: As we said, the values of ideal diode current i_D^i and ideal diode voltage v_D^i **must** be represented by a point **on** the green "curve".

Thus, that point will **either** be on:

1. the **vertical** line, where the ideal diode **voltage is zero** ($v_D^i = 0$), and the ideal diode **current is positive** ($i_D^i \geq 0$), or

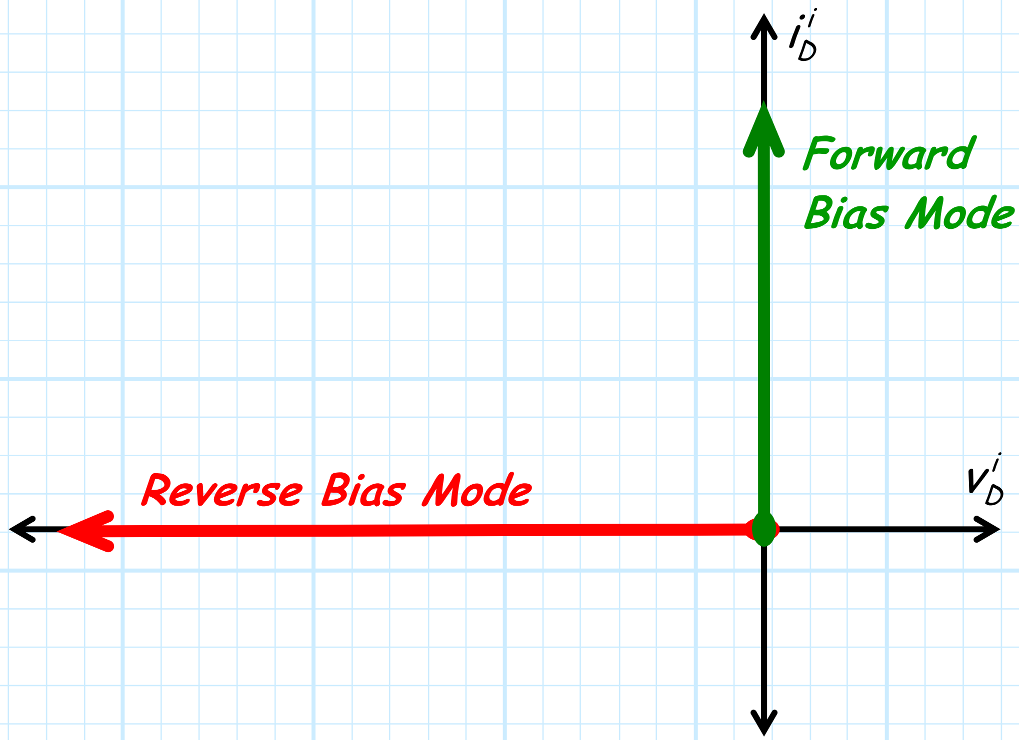
2. the **horizontal** line, where the ideal diode **current is zero** ($i_D^i = 0$), and the ideal diode **voltage is negative** ($v_D^i \leq 0$).

They first tried to give us forwardbias43

We give each of these **two possibilities** a **name**:

Forward Bias Mode - when the ideal diode **voltage is zero** ($v_D^i = 0$), and the ideal diode **current is positive** ($i_D^i \geq 0$), or

Reverse Bias Mode - when the ideal diode **current is zero** ($i_D^i = 0$), and the ideal diode **voltage is negative** ($v_D^i \leq 0$).

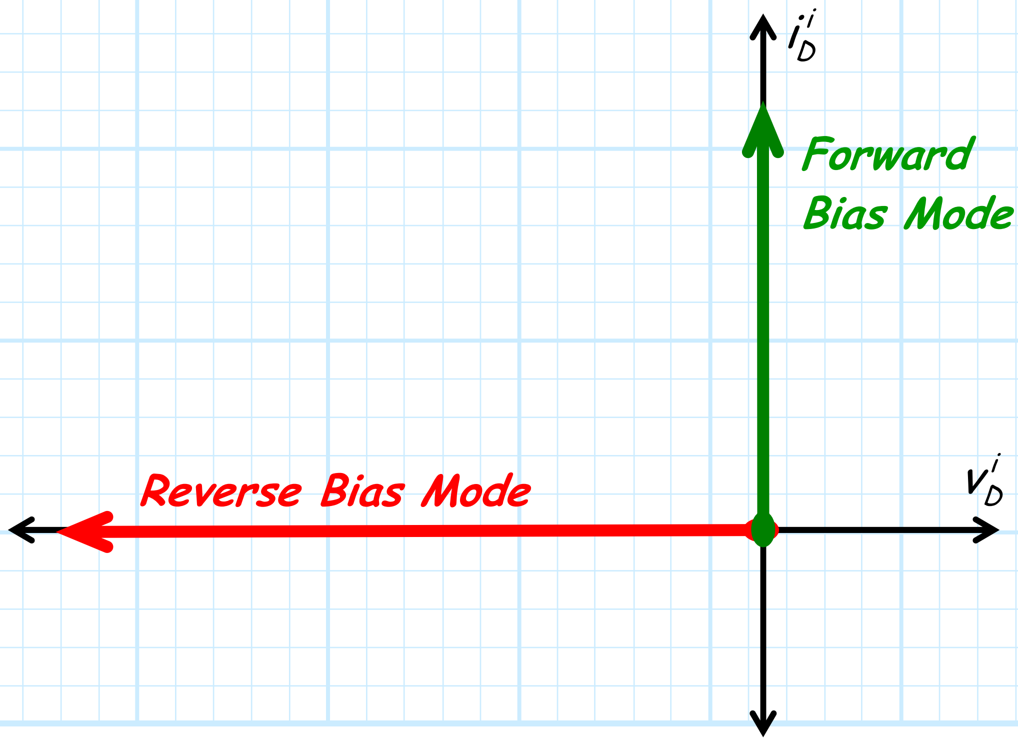


Trust me: memorize this stuff

Commit this to **memory**:

* for the **forward bias mode**, the ideal diode "acts" like a conditional **short** circuit—the voltage across it is zero, **provided** that the **current** through it is **positive**.

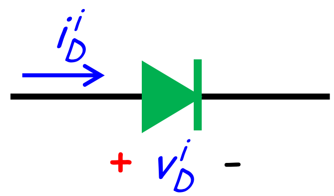
* for the **reverse bias mode**, the ideal diode "acts" like a conditional **open** circuit—the current through it is zero, **provided** that the **voltage** across it is **negative**.



Why can't you all be more like this student?

*Behold the **ideal diode**—the circuit device with a split personality!*

➔ *Is it a **short** ? Or is it an **open** ?*



	$v_D^i < 0$	$v_D^i = 0$	$v_D^i > 0$
$i_D^i > 0$	*invalid*	**forward biased**	*invalid*
$i_D^i = 0$	**reverse biased**	**no bias**	*invalid*
$i_D^i < 0$	*invalid*	*invalid*	*invalid*