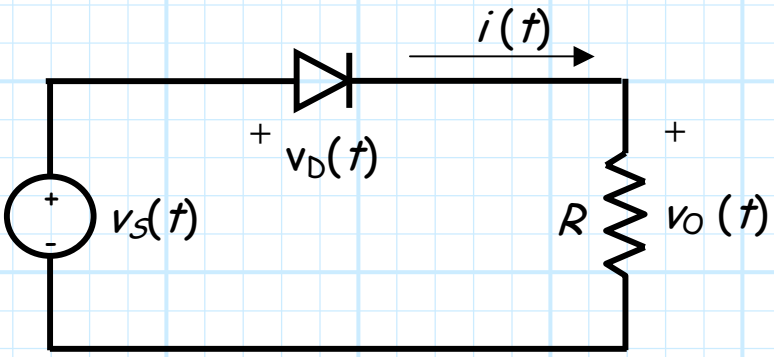
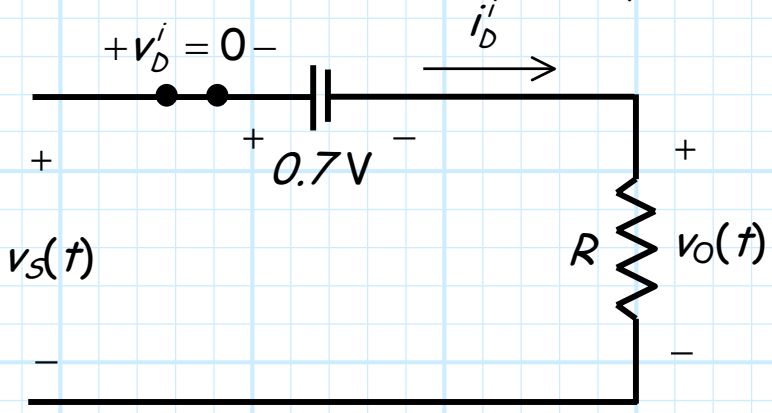
Example: Diode Circuit Transfer Function

Consider the following circuit, called a **half-wave rectifier**:



Let's use the **CVD model** to determine the output voltage v_O in terms of the input voltage v_S. In other words, let's determine the diode circuit **transfer function** $v_O = f(v_S)$!

ASSUME the **ideal** diode is **forward** biased, ENFORCE $v_D^i = 0$.



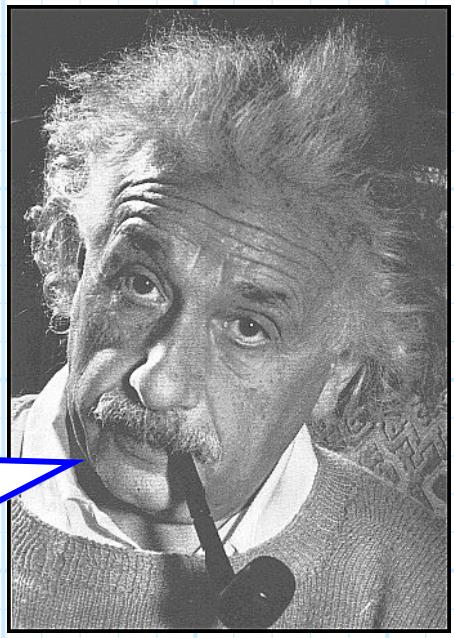
From KVL, we find that:

$$v_O(t) = v_S(t) - 0.7$$

This result is of course true **if** our original assumption is correct—it is valid **if** the ideal diode is forward biased (i.e., $i_D^i > 0$)!

From Ohm's Law, we find that:

$$i_D^i = \frac{v_O}{R} = \frac{v_S - 0.7}{R}$$



Q: *I'm so **confused**! Is this current **greater** than zero or **less** than zero? **Is** our assumption correct? **How** can we tell?*

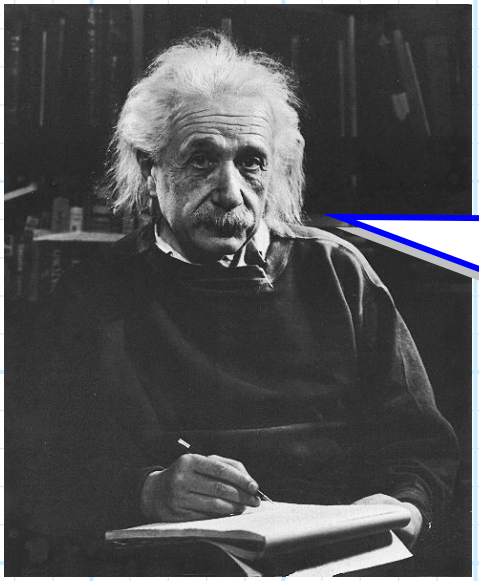
A: The ideal diode current is **dependent** on the value of source voltage $v_S(t)$. As such, we **cannot** determine **if** our assumption is correct, we **instead** must find out **when** our assumption is correct!

In other words, we know that the forward bias assumption is correct **when** $i_D^i > 0$. We can rearrage our diode current expression to determine for what values of source voltage $v_S(t)$ this is true:

$$\begin{aligned} i_D^i &> 0 \\ \frac{v_S(t) - 0.7}{R} &> 0 \\ v_S(t) - 0.7 &> 0 \\ v_S(t) &> 0.7 \end{aligned}$$

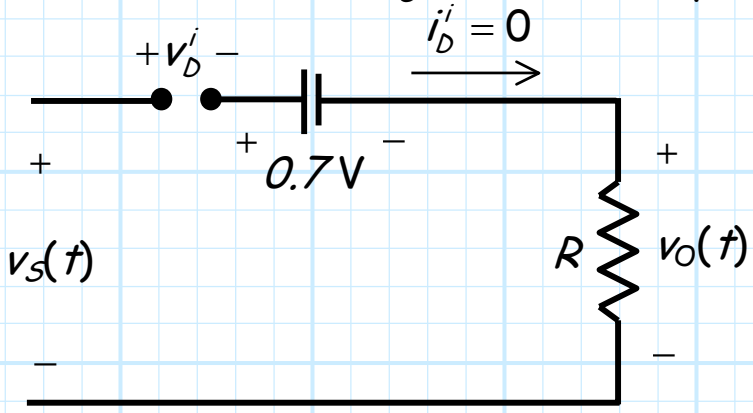
So, we have found that **when** the source voltage $v_S(t)$ is greater than 0.7 V, the output voltage $v_O(t)$ is:

$$v_O(t) = v_S(t) - 0.7$$



Q: *OK, I've got this result written down. However, I still don't know what the output voltage $v_O(t)$ is **when** the source voltage $v_S(t)$ is **less** than 0.7V!?!*

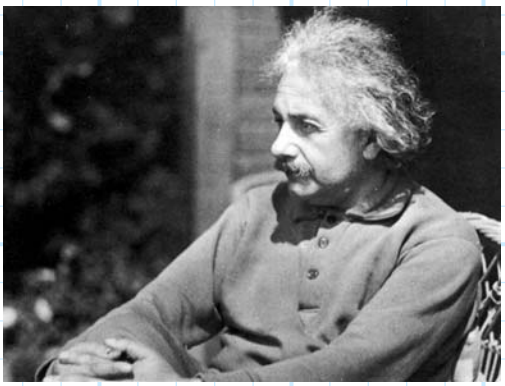
Now we **change** our assumption and ASSSUME the ideal diode in the CVD model is **reverse** biased, an assumption ENFORCEd with the condition that $i_D^i = 0$ (i.e., an open circuit).



Q: *Fascinating! The output voltage is **zero** when the ideal diode is reverse biased. But, precisely when **is** the ideal diode reverse biased? For **what** values of v_S does this occur ?*

From Ohm's Law, we find that the output voltage is:

$$\begin{aligned} v_O &= R\, i_D^i \\ &= R\,(0) \\ &= 0 \text{ V} \quad !!! \end{aligned}$$



A: To answer these questions, we must determine the **ideal** diode voltage in **terms** of v_S (i.e., $v_D^i = f(v_S)$):

From KVL: $$v_S - v_D^i - 0.7 = v_O$$

Therefore:

$$\begin{aligned} v_D^i &= v_S - 0.7 - v_O \\ &= v_S - 0.7 - 0.0 \\ &= v_S - 0.7 \end{aligned}$$

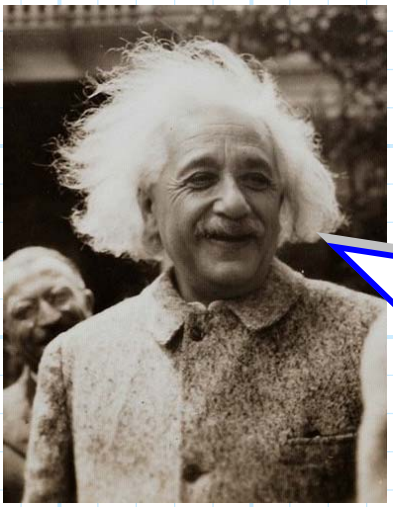
Thus, the ideal diode is in reverse bias **when:**

$$v_D^i < 0$$
$$v_S - 0.7 < 0$$

Solving for v_S, we find:

$$v_S - 0.7 < 0$$
$$v_S < 0.7 \text{ V}$$

In other words, we have determined that the **ideal** diode will be reverse biased **when** $v_S < 0.7$ V, and that the output voltage will be $v_O = 0$.



Q: *So, we have found that:*

$v_O = v_S - 0.7$ *when* $v_S > 0.7$ V

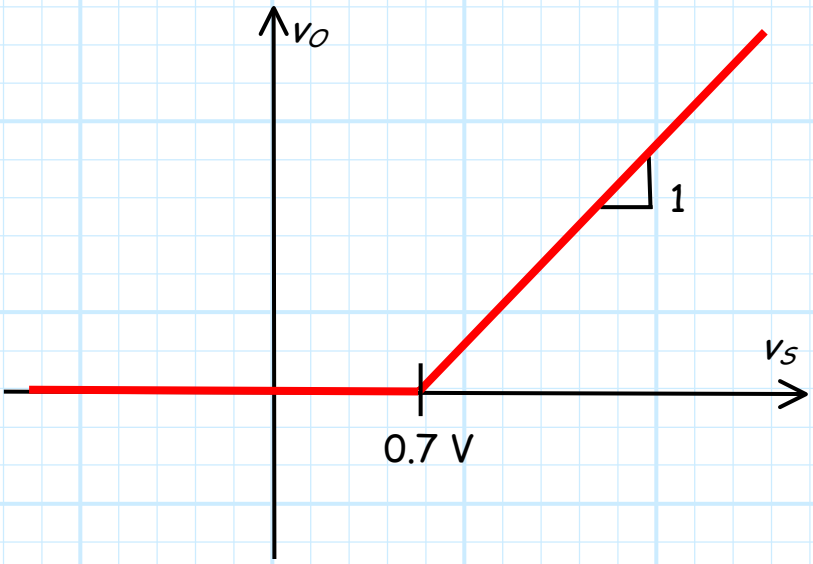
and,

$v_O = 0.0$ *when* $v_S < 0.7$ V

*It **appears** we have a **valid, continuous, function**!*

A: That's right! The **transfer function** for this circuit is therefore:

$$v_O = \begin{cases} v_S - 0.7 & for \quad v_S > 0.7 \\ 0 & for \quad v_S < 0.7 \end{cases}$$



*Although the circuit in this example may **seem** trivial, it is actually **very important**!*

*It is called a **half-wave rectifier**, and provides signal **rectification**.*

*Rectifiers are an **essential** part of every AC to DC **power supply**!*