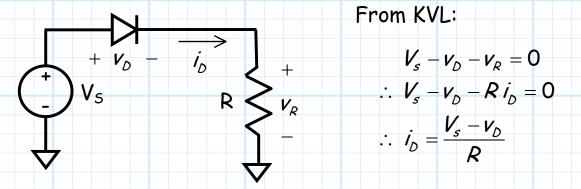# Transcendental Solutions of Junction Diode Circuits

In a previous example, we were able to use the junction diode equation to **algebraically** analyze a circuit and find **numeric** solutions for all circuit currents and voltages.

However, we will find that this type of circuit analysis is, in general, often **impossible** to achieve using the junction diode equation!

Q: *Impossible !?!* **I** *must intercede, and point out that* **you** *are clearly wrong. If* **I** *have an explicit mathematical description of each device in a circuit (which* **I** *do for a junction diode),* **I** *can use KVL and KCL to analyze* **any** *circuit.*

A: Although we can always determine a numerical solution, it is often impossible to find this solution **algebraically**. Consider this **simple** junction diode circuit:

From KVL:

$$V_s - v_D - v_R = 0$$

$$\therefore V_s - v_D - R\,i_D = 0$$

$$\therefore i_D = \frac{V_s - v_D}{R}$$

Likewise, from the **junction** diode equation:

$$i_D = I_s \left(e^{v_D/nV_T} - 1 \right)$$

Equating these two, we have a **single** equation with a **single** unknown (v_D):

$$\frac{V_s - v_D}{R} = I_s \left(e^{v_D/nV_T} - 1 \right)$$

Q: *Precisely! Just as **I** said! You have 1 equation with 1 unknown. Go solve this equation for v_D, and then you can determine all other unknown voltages and currents (i.e., i_D and v_R).*

A: But that's the problem! What **is** the algebraic solution of v_D for the equation:

$$\frac{V_s - v_D}{R} = I_s \left(e^{v_D/nV_T} - 1 \right)$$

????

The above equation is known as a **transcendental equation**. It is an algebraic expression for which there is **no** algebraic solution!

Examples of transcendental equations include:

$$x = cos[x], \quad y^2 = ln[y], \quad \text{or} \quad 4 - x = 2^x$$

Q: *But, we could build that simple junction diode circuit in the lab. Therefore v_D, i_D and v_R must have **some** numeric value, right !?!*

A: Absolutely! For every value of source voltage V_s, resistance R, and junction diode parameters n and I_s, there is a specific numerical solution for v_D, i_D and v_R. However, we **cannot** find this **numerical** solution with **algebraic** methods!

Q: *Well then how the heck do we find solution??*

A: We use what is know as **numerical methods**, often implementing some **iterative** approach, typically with the help of a **computer** (see example 3.4 on pp. 154-155).

This generally involves **more work** than we wish to do when analyzing junction diode circuits!

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

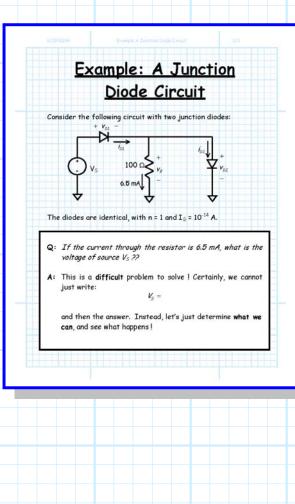**A:** We replace the junction diodes with **circuit models** that **approximate** junction diode behavior!

Q: *Oh you're tricky, but you are still clearly **wrong**. Recall in an **earlier example** we analyzed a junction diode circuit, but we did **not** use "approximate models" nor "numerical methods" to find the answer!*

A: This is absolutely correct; we did **not** use approximate models or numerical methods to solve that problem. However, if you look back at that example, you will find that the problem was a bit **contrived**.

* Recall that effectively, we were **given** the voltage across one diode as part of the problem statement. We were then asked to find the **source voltage** V_s.

* This was a bit of an **academic** problem, as in the "real world" it is **unlikely** that we would somehow know the voltage across the diode without knowing the value of the voltage source that produced it!

*   Thus, problems like this previous example are sometimes used by professors to create junction diode circuit problems that are solvable, **without** encountering a dreaded **transcendental equation**!

*   In the real world, we typically know **neither** the diode voltage **nor** the diode current directly—transcendental equations are most often the **sad** result!

*   **Instead** of applying numerical techniques, we will find it much faster (albeit slightly less accurate) to apply **approximate circuit models**.

*I wish I had a **nickel** for every time my software has **crashed**— Oh wait, **I do**!*