EE40
Lecture 28
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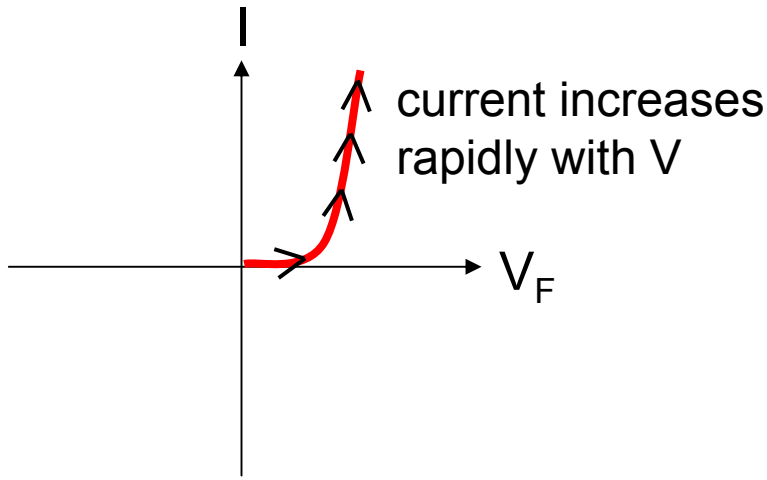
4/09/08

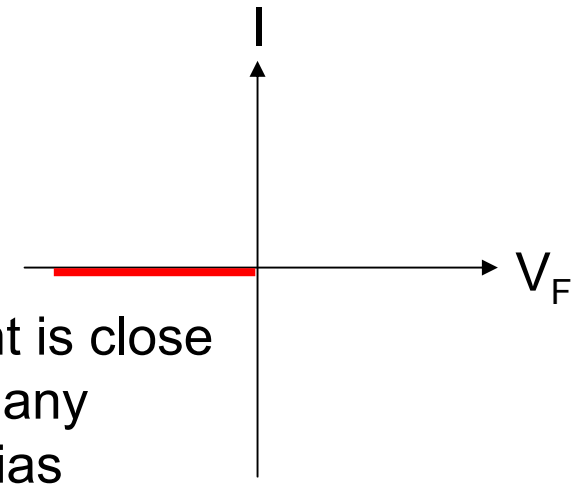
Reading: Chap. 10: Diodes

I-V Characteristics

In forward bias (+ on p-side) we have almost unlimited flow (very low resistance). Qualitatively, the I-V characteristics must look like:



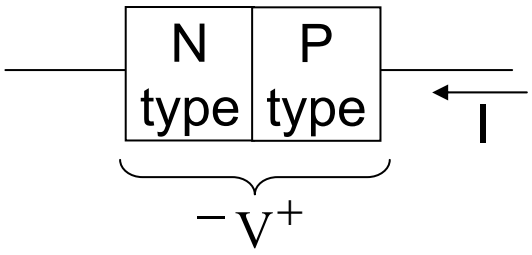
In reverse bias (+ on n-side) almost no current can flow. Qualitatively, the I-V characteristics must look like:



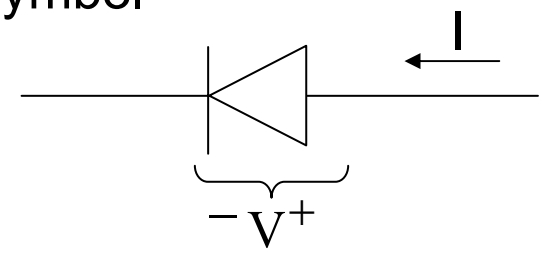
The current is close to zero for any negative bias

Diode Physical Behavior and Equation

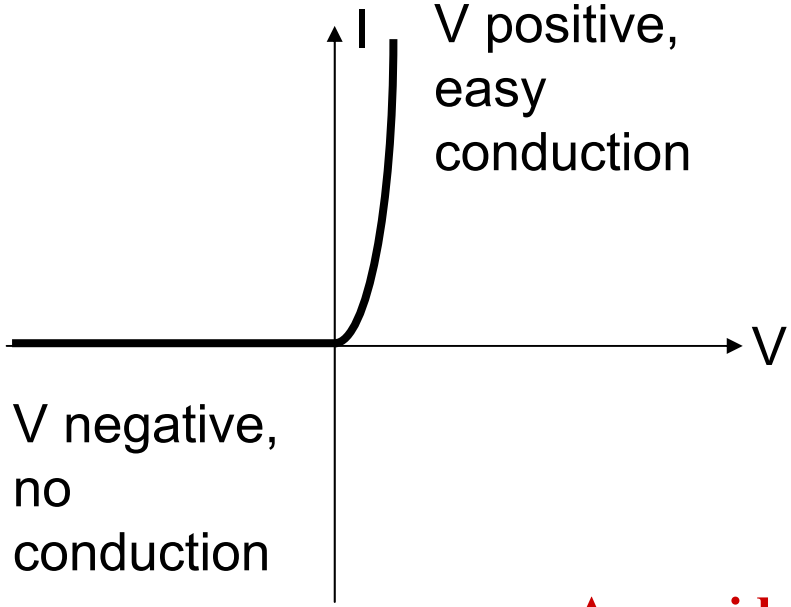
Schematic Device



Symbol



Qualitative I-V characteristics:



Quantitative I-V characteristics:

$$I = I_0(e^{qV/kT} - 1)$$

In which kT/q is 0.026V and I_O is a constant depending on diode area. Typical values: 10^{-12} to 10^{-16} A. Interestingly, the graph of this equation looks just like the figure to the left.

A non-ideality factor n times kT/q is often included.

The pn Junction I vs. V Equation

I-V characteristic of PN junctions

In EECS 105, 130, and other courses you will learn why the I vs. V relationship for PN junctions is of the form

$$I = I_0(e^{qV/kT} - 1)$$

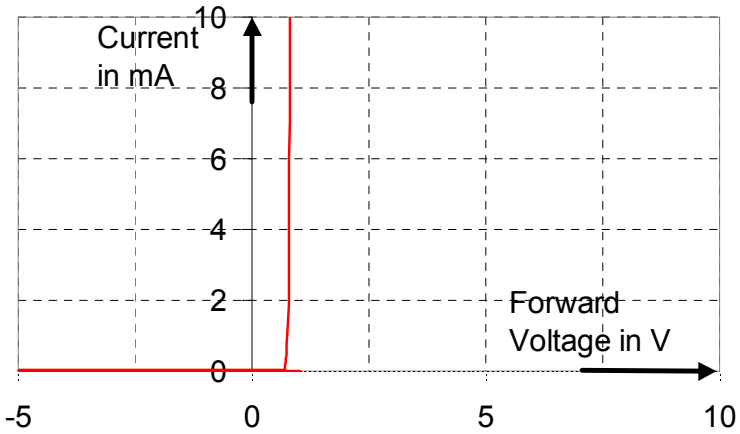
where I_0 is a constant proportional to junction area and depending on doping in P and N regions, $q = \text{electronic charge} = 1.6 \times 10^{-19}$,
k is Boltzman constant, and T is absolute temperature.
$KT/q = 0.026\text{V at} 300°\text{K}$, a typical value for I_0 is $10^{-12} - 10^{-15}\,\text{A}$

We note that in forward bias, I increases **exponentially** and is in the μA-mA range for voltages typically in the range of 0.6-0.8V.
In reverse bias, the current is essentially zero.

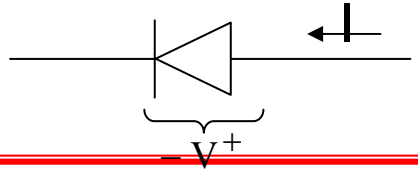
Diode Ideal (Perfect Rectifier) Model

The equation $I = I_0 \exp(qV/kT - 1)$

is graphed below for $I_0 = 10^{-15}$ A

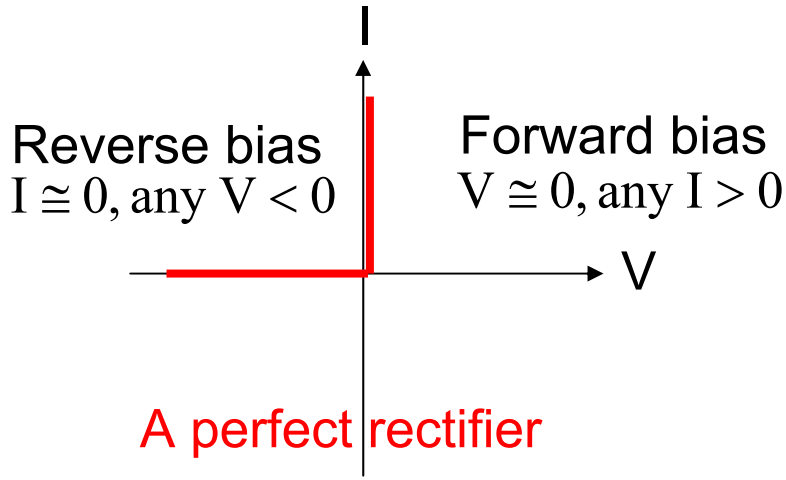


The characteristic is described as a "rectifier" – that is, a device that permits current to pass in only one direction. (The hydraulic analog is a "check value".) Hence the symbol:

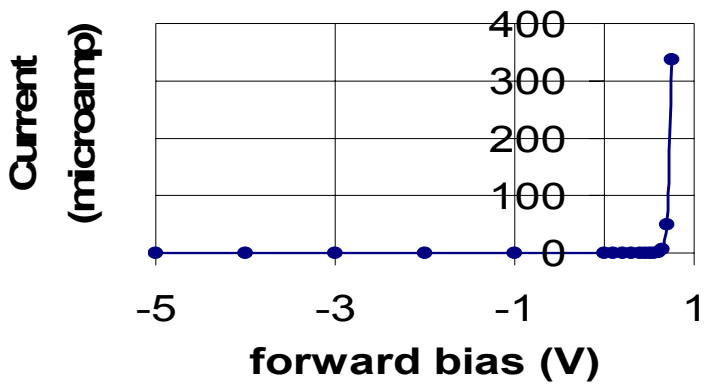


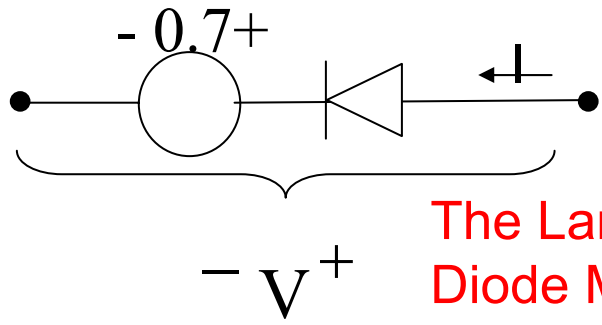
Simple "Perfect Rectifier" Model

If we can ignore the small forward-bias voltage drop of a diode, a simple effective model is the "perfect rectifier," whose I-V characteristic is given below:



Diode Large-Signal Model (0.7 V Drop)

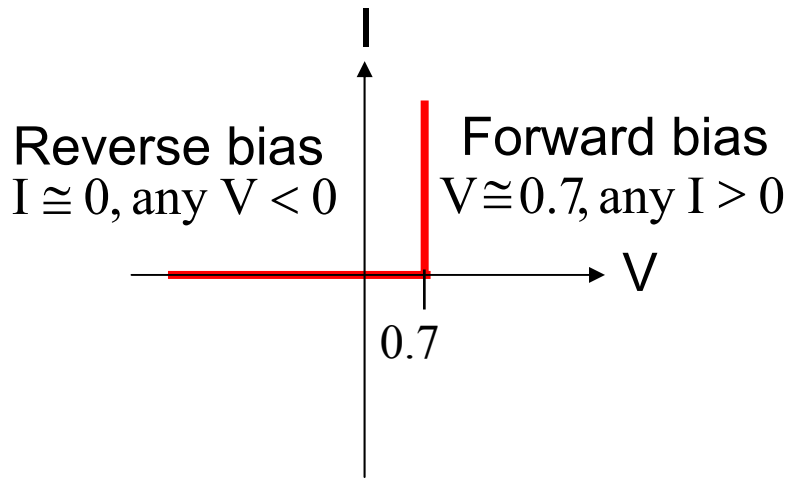




The Large-Signal Diode Model

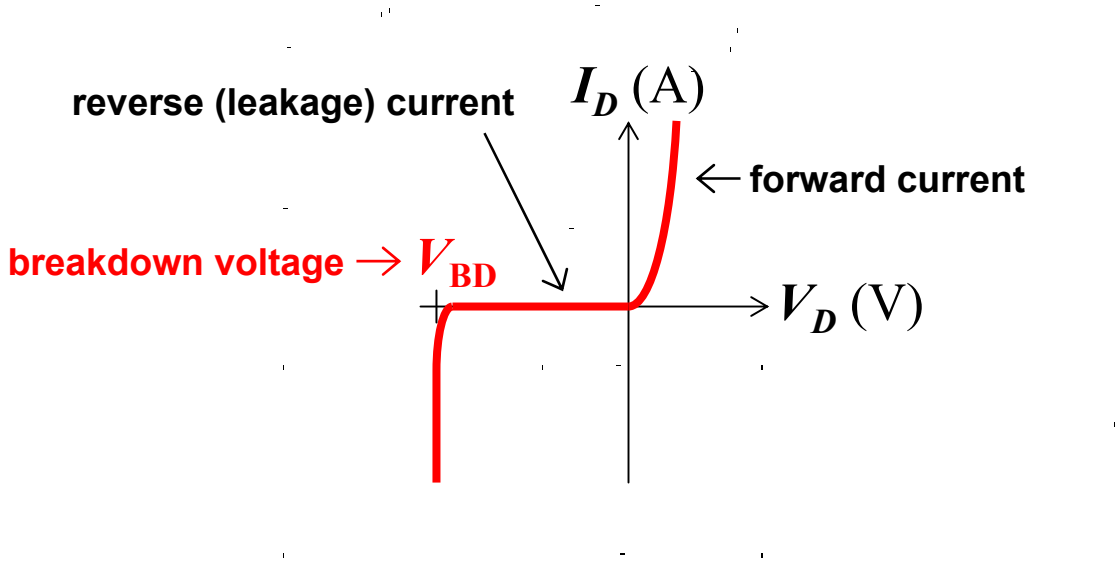
Improved "Large-Signal Diode" Model:

If we choose not to ignore the small forward-bias voltage drop of a diode, it is a very good approximation to regard the voltage drop in forward bias as a constant, about 0.7V. the "Large signal model" results.



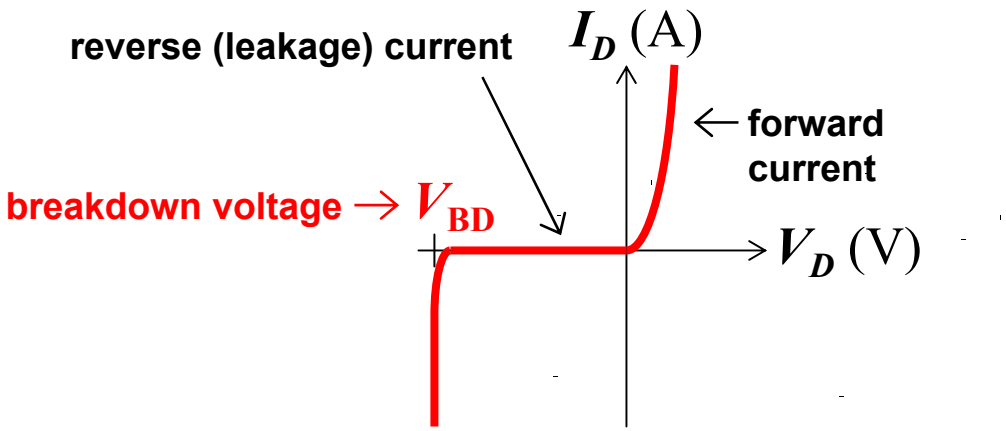
pn-Junction Reverse Breakdown

- As the reverse bias voltage increases, the peak electric field in the depletion region increases. When the electric field exceeds a critical value ($E_{crit} \cong 2\text{x}10^5$ V/cm), the reverse current shows a dramatic increase:



Zener Diode

A ***Zener diode*** is designed to operate in the breakdown mode.



Example: