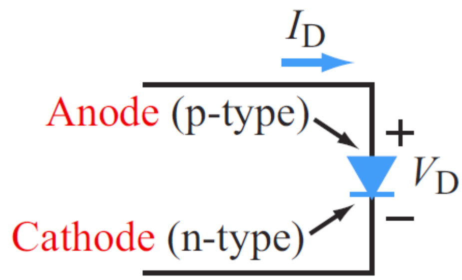
Diodes

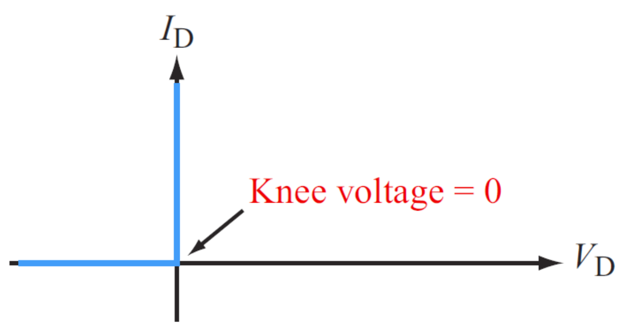
The diode is a mainstay of solid-state circuits. Its circuit schematic symbol is shown below with V_D as the voltage across the diode, defined such that the (+) side is at the anode terminal of the diode and the (−) side at its cathode terminal.



There are many types of diodes, including the basic pn-junction diode, the Zener and Schottky diodes, and the ubiquitous light emitting diode (LED) used in consumer electronics. For the present, we will limit our discussion to the pn-junction diode, commonly referred to simply as the diode.

The pn diode consists of a p-type semiconductor placed in contact with an n-type semiconductor, thereby forming a junction. The p-type material is so named because the impurities that have been added to its bulk material result in a crystalline structure in which the available charged carriers are predominantly positive charges. The opposite is true for the n-type material; different types of impurities are added to the bulk material, as a result of which the predominant carriers are negative charges (electrons). In the absence of a voltage across the diode, the two sets of carriers diffuse away from each other at the edge of the junction, generating an associated built in potential barrier (voltage), called the forward-bias voltage or offset voltage V_F.

The main use of the diode is as a one-way valve for current. If the diode were ideal, the i-v current would look like this:

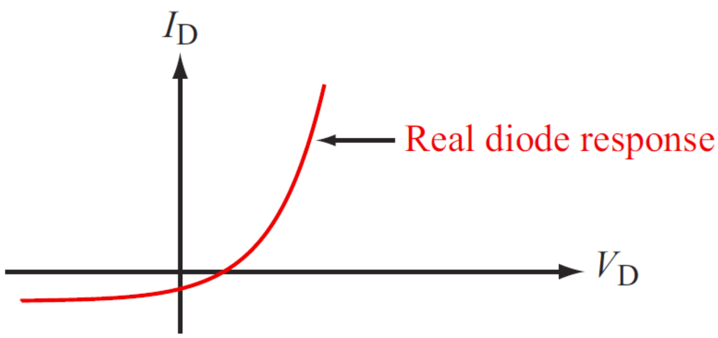


In an ideal diode, current can flow through the diode from the (+) terminal to the (−) terminal unimpeded, regardless of its magnitude, but it cannot flow in the opposite direction.

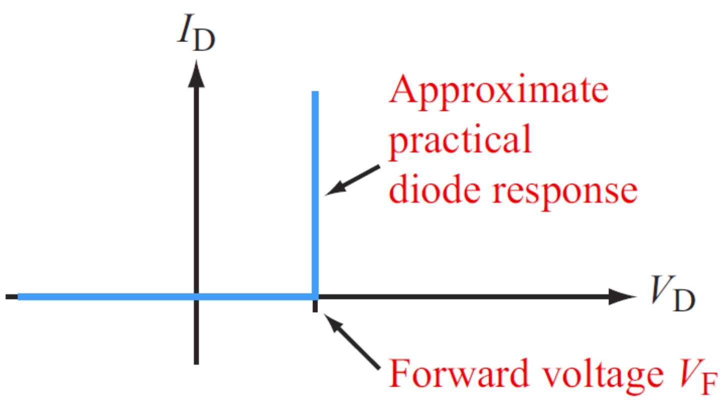
In other words, an ideal diode looks like a short circuit for positive values of V_D and like an open circuit for negative values of V_D. These two states are called **forward bias** and **reverse bias**, respectively. When a positive-bias voltage exceeding V_F is applied to the diode, the potential barrier is counteracted, allowing the flow of current from p to n (which includes positive charges flowing in that direction as well as negative charges flowing in the opposite direction). On the other hand, if a negative-bias voltage is applied to the diode, it adds to the potential barrier, further restricting the flow of charges across the barrier and resulting in no current flow from n to p.

The voltage level at which the diode switches from reverse bias to forward bias is called the **knee voltage** or **forward-bias voltage**. For the ideal diode, $V_F = 0$ and the knee is at $V_D = 0$, which means that the forward bias segment of its i–υ characteristic is aligned perfectly along the I_D-axis.

Real diodes differ from the ideal diode model in two important respects: (1) the knee in the curve is not at $V_D = 0$, and (2) the diode does not behave exactly like a perfect short circuit when in forward bias nor like a perfect open circuit when in reverse bias.



Note how nonlinear a real diode really is! For many electrical engineering applications, however, the nonlinearities are not so important, and the approximate ideal-like diode model shown below is quite sufficient.



The only difference between the ideal diode model and the approximate diode model above is that in the latter the transition from reverse to forward bias occurs at a non-zero, positive value of V_D, namely the forward-bias voltage V_F. For a silicon pn-junction diode, a typical value of V_F is 0.7 V. We always should remember that V_F is a property of the diode itself, not of the circuit it is a part of.