Real diodes are modelled by a junction diode in series with a bulk resistance, R_B.
The characteristic curve of I versus V has a knee voltage.

Material	Approximate knee voltage
Ge	0.3
Si	0.7
GaAs	2.0
SiC	2.7

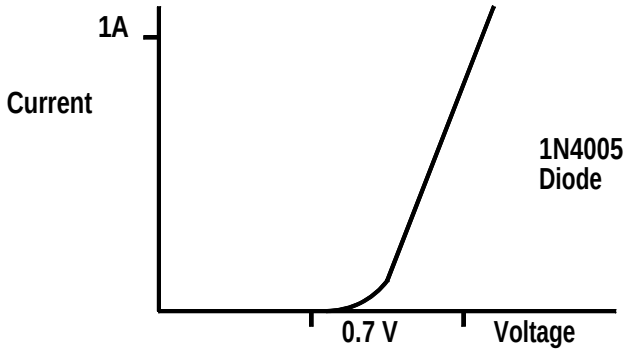
Below the knee voltage, the diode equation

$$I = I_0 \exp\left(\frac{eV}{kT}\right) = I_0 \exp\left(\frac{V}{25mV}\right)$$

dominates the characteristic of a real diode.

Above the knee voltage, the bulk resistance, R_B, dominates the characteristic of a real diode.

R_B is typically of the order of 1Ω.
The bulk resistance prevents the large currents predicted by the junction equation, for large forward bias voltages, from flowing in real diodes.



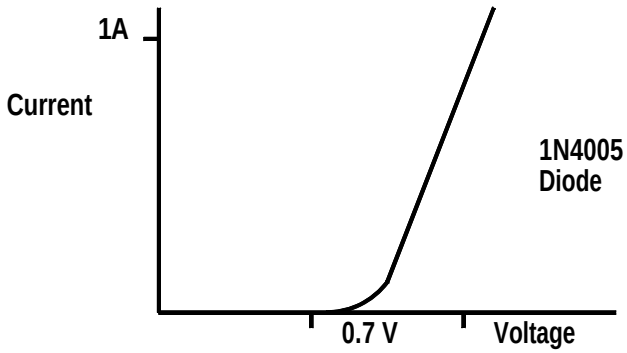
Measured I–V characteristic of a real silicon diode

For voltages less than 0.7V the current is so small that it hardly shows on the graph

For voltages below about 0.7V the current is controlled by the diode junction and is related to the voltage by

$$I = I_0 \exp\left(\frac{V}{25mV}\right)$$

This is called the small signal region of operation.



Measured I–V characteristic of a real silicon diode

For voltages above 0.7V, the exponential junction relationship no longer governs the current through the diode. The current is now limited by the bulk resistance, R_B, of the diode which is due to
the series resistances of the of the p and n type material,
the ohmic contacts and
the copper connecting leads.

We can model this real diode by a pn junction with the exponential characteristic and a series bulk resistance as shown

The transition voltage between the two types of behaviour is called the knee voltage
The values of the knee voltages for different types of semiconductor material have been shown in the table

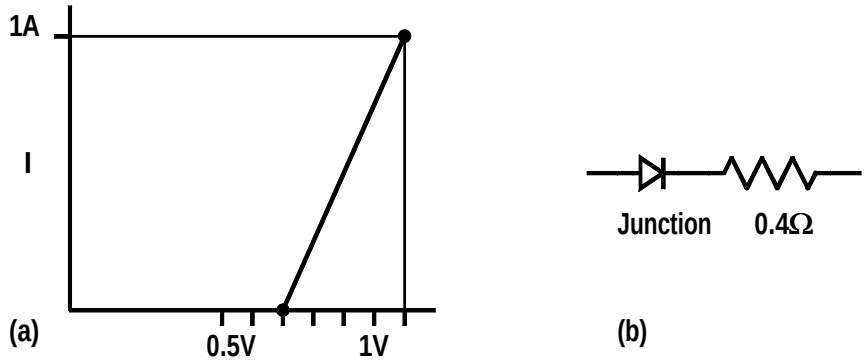
Bulk resistance depends on design application

A rectifier diode designed to pass currents of the order of 5A will have a bulk resistance of the order of $R_B = 0.1\Omega$.

A small point contact diode, which is optimised for high operating frequency but which will only pass small currents, will have a bulk resistance of the order of $R_B = 5\Omega$.

The bulk resistance is determined by measuring the change of current for a change of voltage in the straight section of the characteristic above the knee voltage.

This gives what is called a dynamic resistance—a slope.



A 1N4005 type silicon diode passes 1.0A for a forward voltage of 1.1V. Sketch the diode characteristic and calculate the bulk resistance of the diode.

Draw the I–V axes as shown. Mark (1.1V, 1A).
Mark the point (0.7V, 0A).
Join these points as shown.
Dynamic Resistance:—

$$R_{Dyn} = \frac{1}{slope} = \frac{1.1V - 0.7V}{1A - 0A} = 0.4\Omega$$

Unit 25 Characteristics of real diodes

Diode type	V	I	V_k	R_B
1N4148	1.0	80mA		
	0.8	30mA		
	0.5	50 μA		
1N4005	1V	200mA		
	0.8	100mA		
	0.6	2mA		
	0.4	20μA		
OA91	0.7V	1mA		
	0.5	100μA		
	0.4	2μA		
OA47	0.6	50mA		
	0.3	2mA		
	0.25	200μA		
	0.2	50μA		
	-5.0	-0.1μA		
Red led	3.0	60mA		
	2.5	40mA		
	2.0	10mA		
	1.8	0mA		
Green led	3.0	90mA		
	2.5	45mA		
	2.0	10mA		
	1.8	0mA		
Blue led	4.0	40mA		
LB5410	3.0	10mA		
	2.5	0mA		