Diode

Chapter Objectives

- To study and understand the structure of diode.
- To know different types of diodes.
- To study and understand the applications of diodes in different circuits.

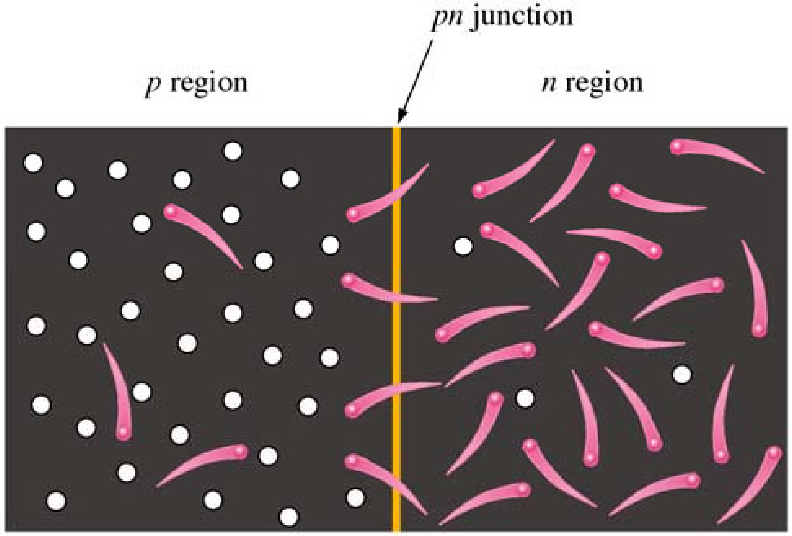
Contents

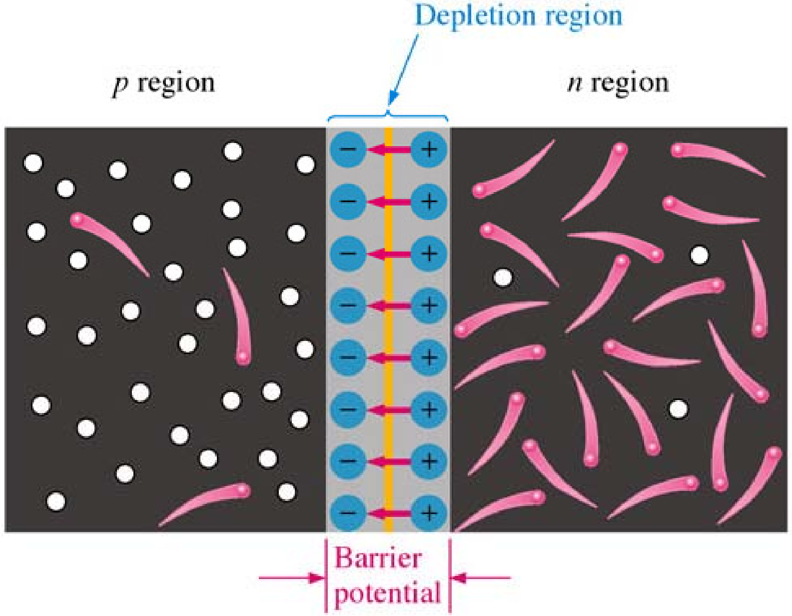
- The PN Junction
- Characteristic Curves of Diodes
- Diode Lead Identification
- Diode Types and Applications

Concept

- **Diodes have both P-regions and N-regions. The boundaries are called junctions.**
- **The P-region is the anode side. The N-region is the cathode side.**
- **There are three possible bias conditions: zero, forward, and reverse.**
- **Zero bias is accompanied by a depletion region.**
- **Forward bias can collapse the depletion region.**
- **Reverse bias enhances the depletion region.**
- **Bias determines if diodes will be off or on.**

The depletion region



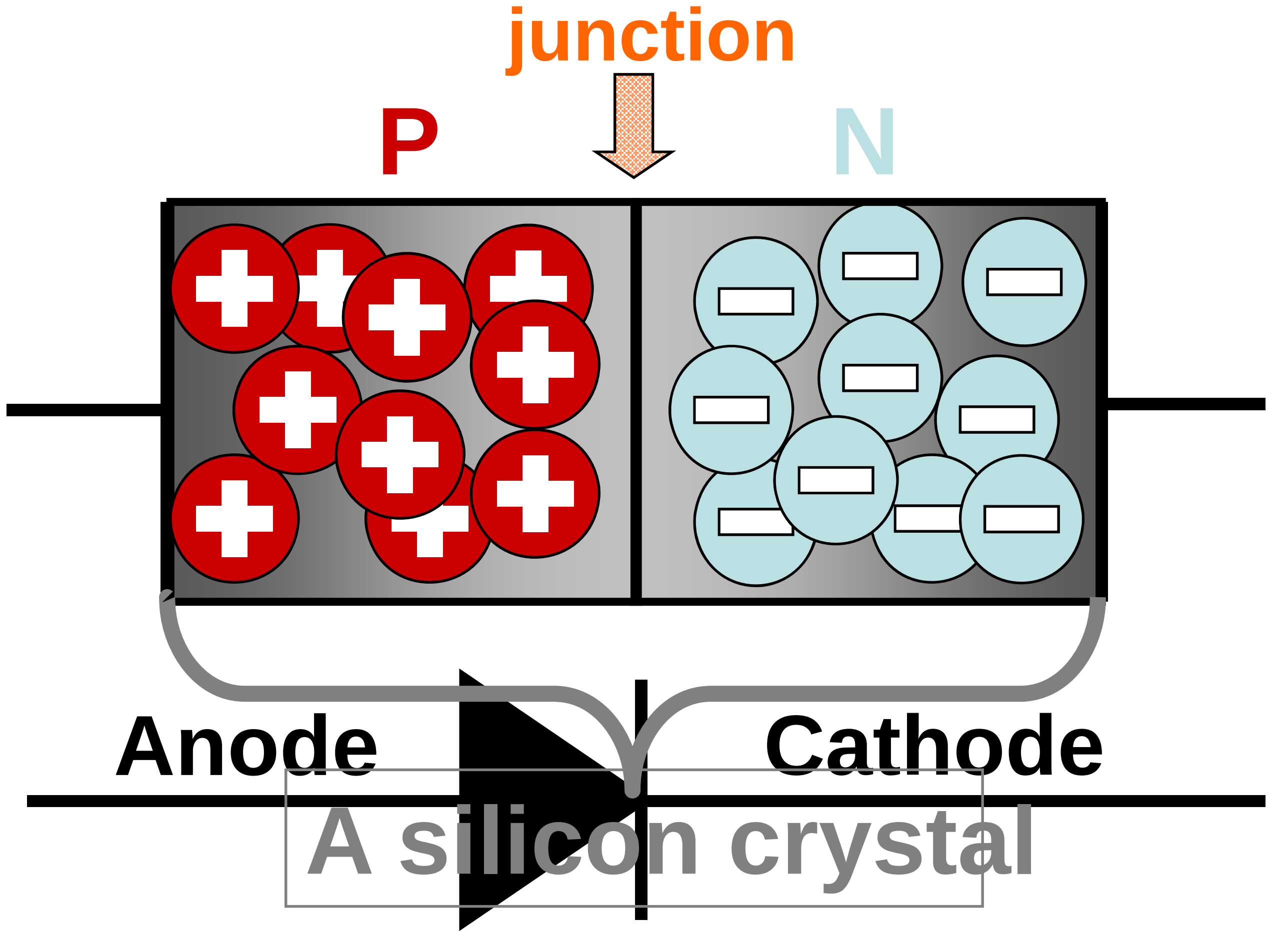


With the formation of the p and n materials combination of electrons and holes at the junction takes place.

This creates the depletion region and has a barrier potential. This potential cannot be measured with a voltmeter but it will cause a small voltage drop.

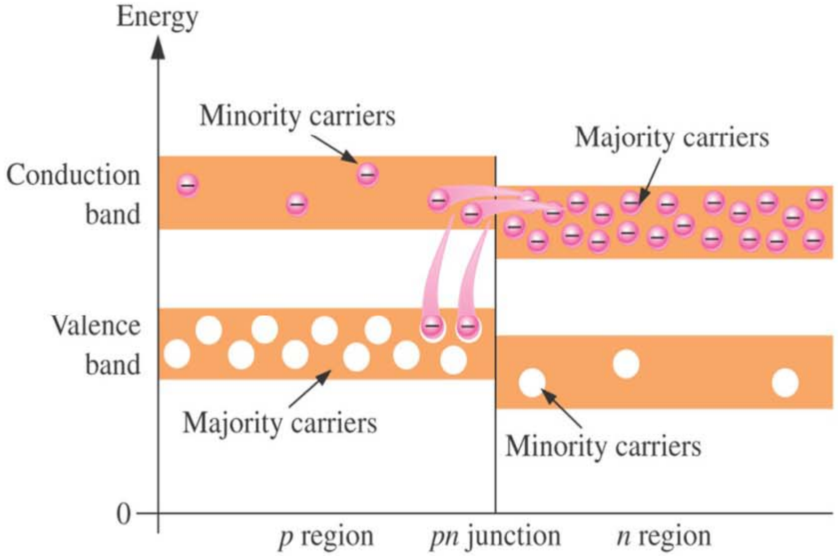
The P-side of a junction diode is doped with acceptor atoms.

The N-side of a junction diode is doped with donor atoms.

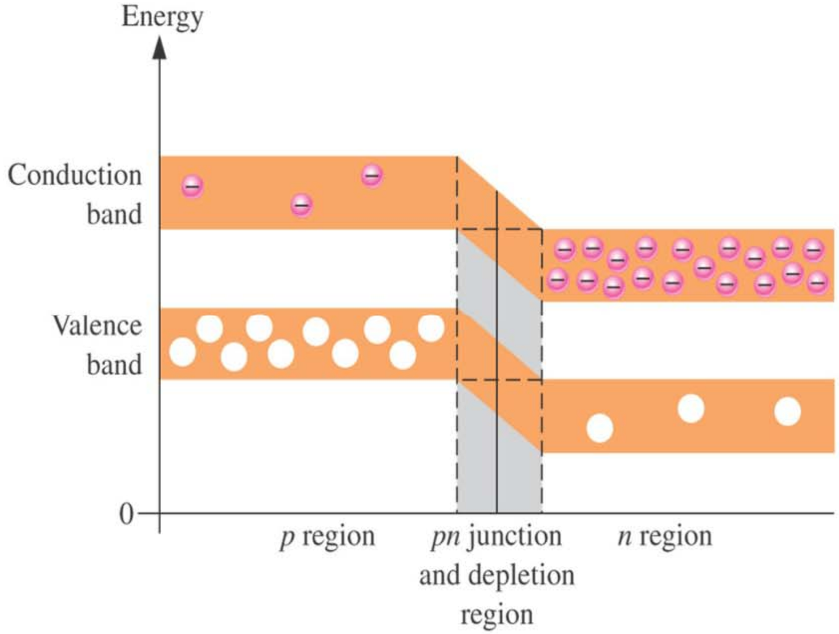


Schematic Symbol

Energy Diagram and Depletion Region



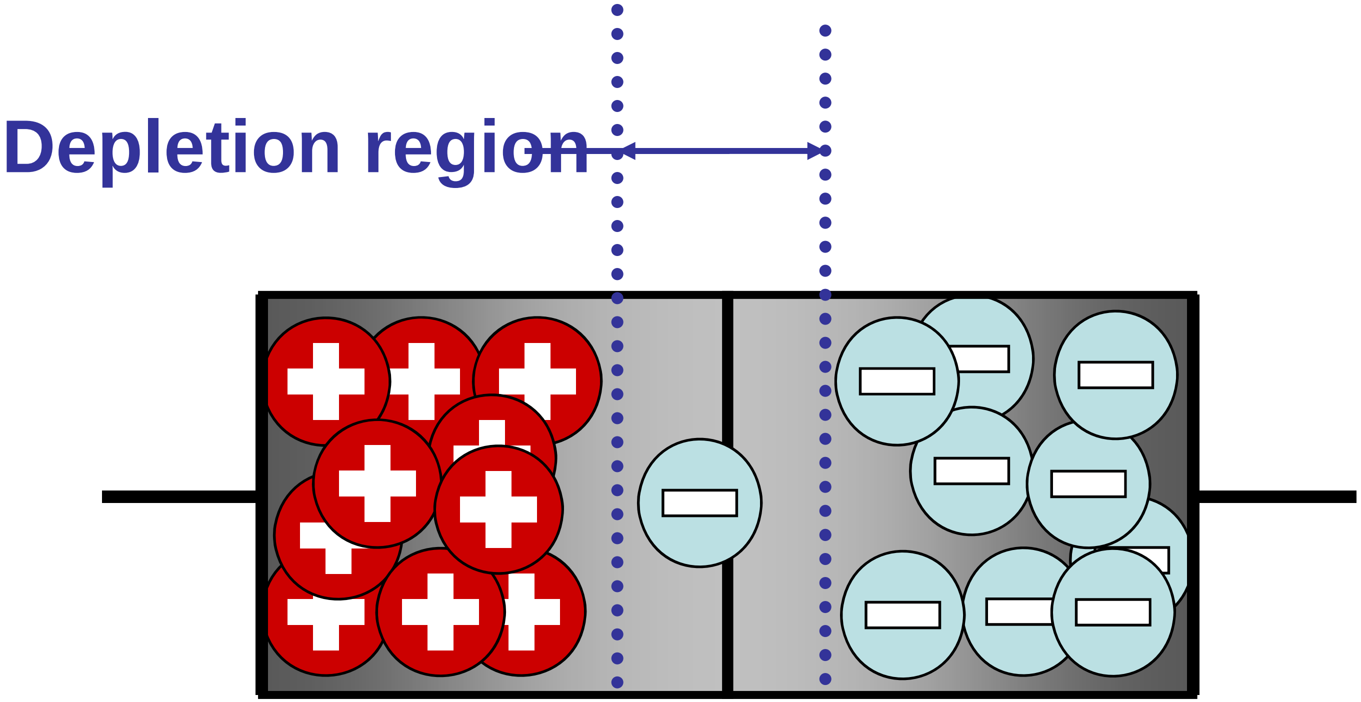
(a) At the instant of junction formation



(b) At equilibrium

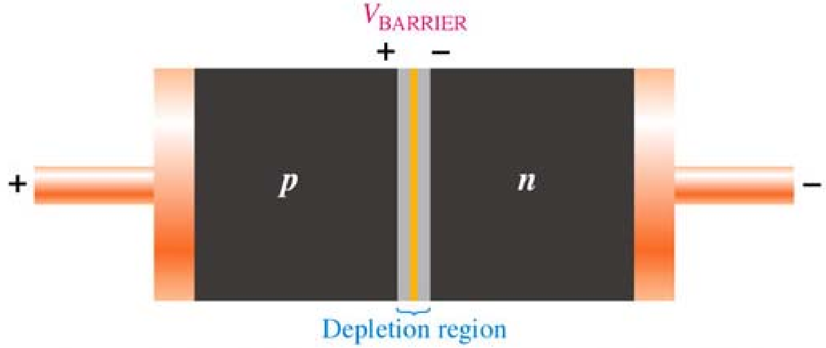
Zero Bias

The electrons near the junction cross over and fill the holes near the junction.



Having no carriers, the depletion region is an insulator.

Forward and Reverse Bias(1)

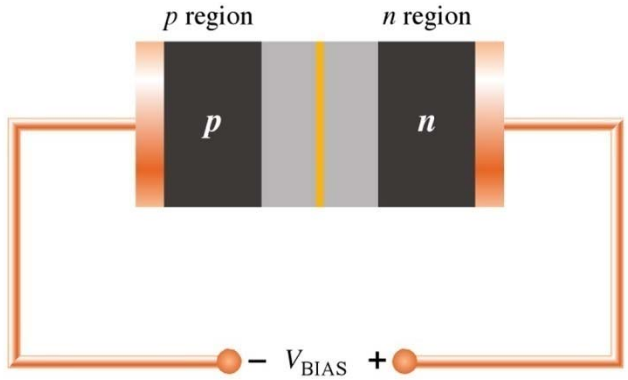


(b) Forward bias narrows the depletion region and produces a voltage drop across the *pn* junction equal to the barrier potential.

-Voltage source or bias connections are + to the p material and – to the n material.

-Bias must be greater than .3 V for Germanium or .7 V for Silicon diodes.

-The depletion region narrows.



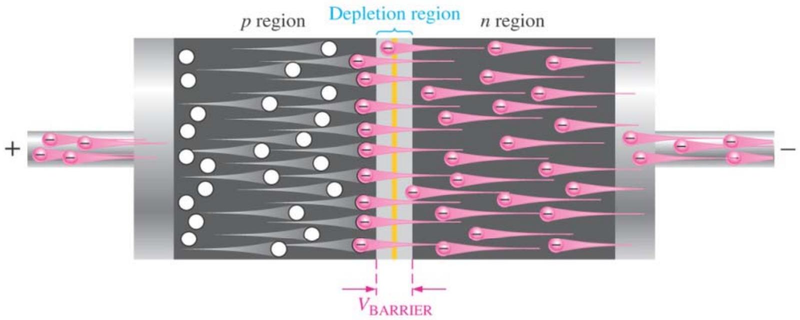
-Voltage source or bias connections are – to the p material and + to the n material.

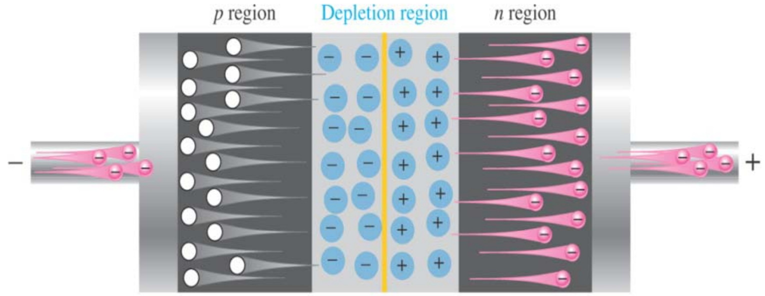
-Bias must be less than the breakdown voltage.

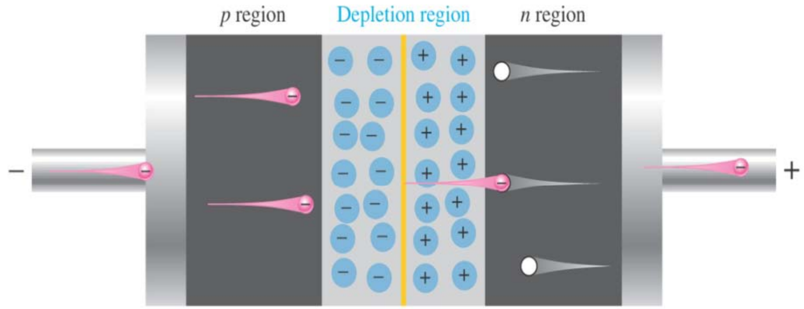
-Current flow is negligible in most cases.

-The depletion region widens.

Forward and Reverse Bias(2)



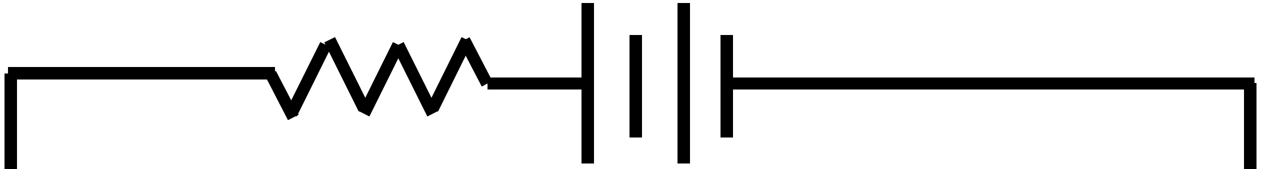




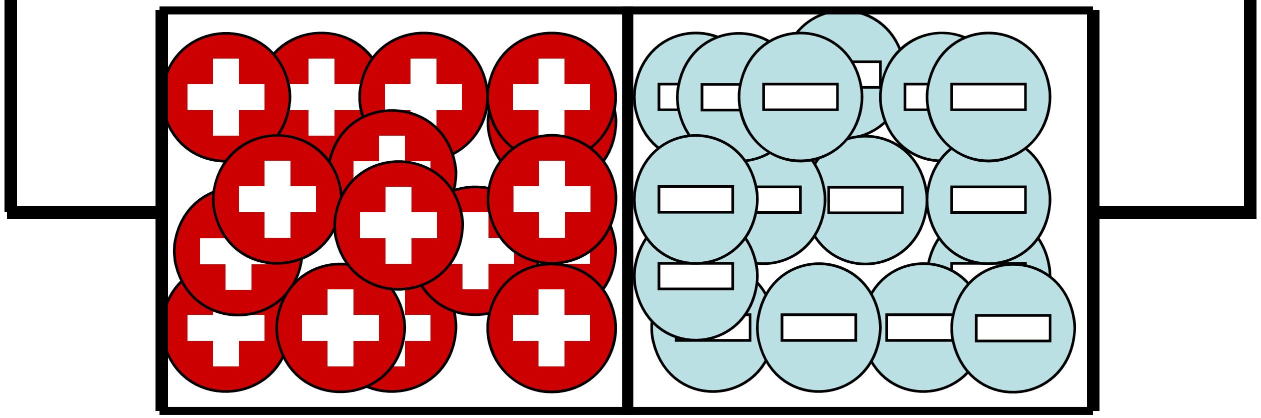
Forward Bias

Reverse Bias

Forward Bias

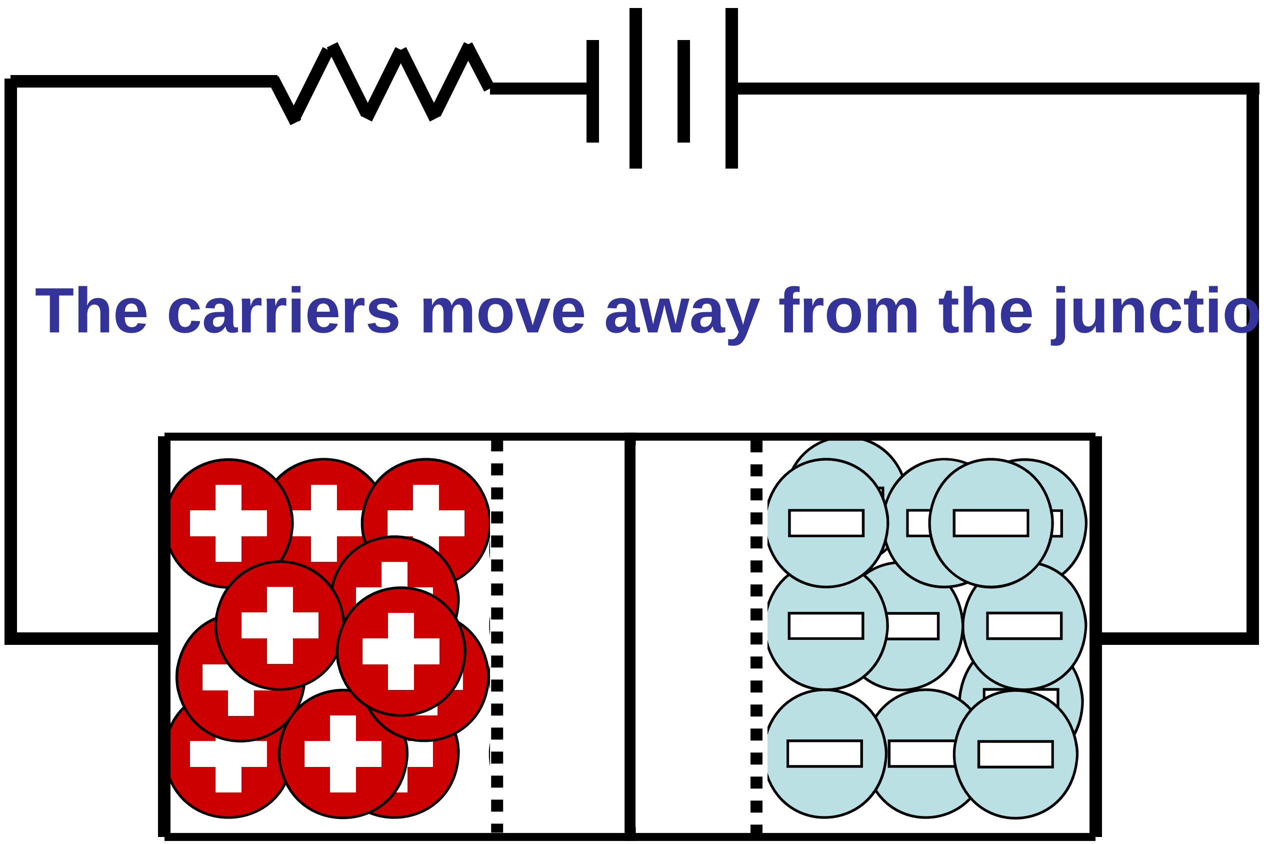


The carriers move toward the junction and collapse the depletion region.



The diode is on.

Reverse Bias

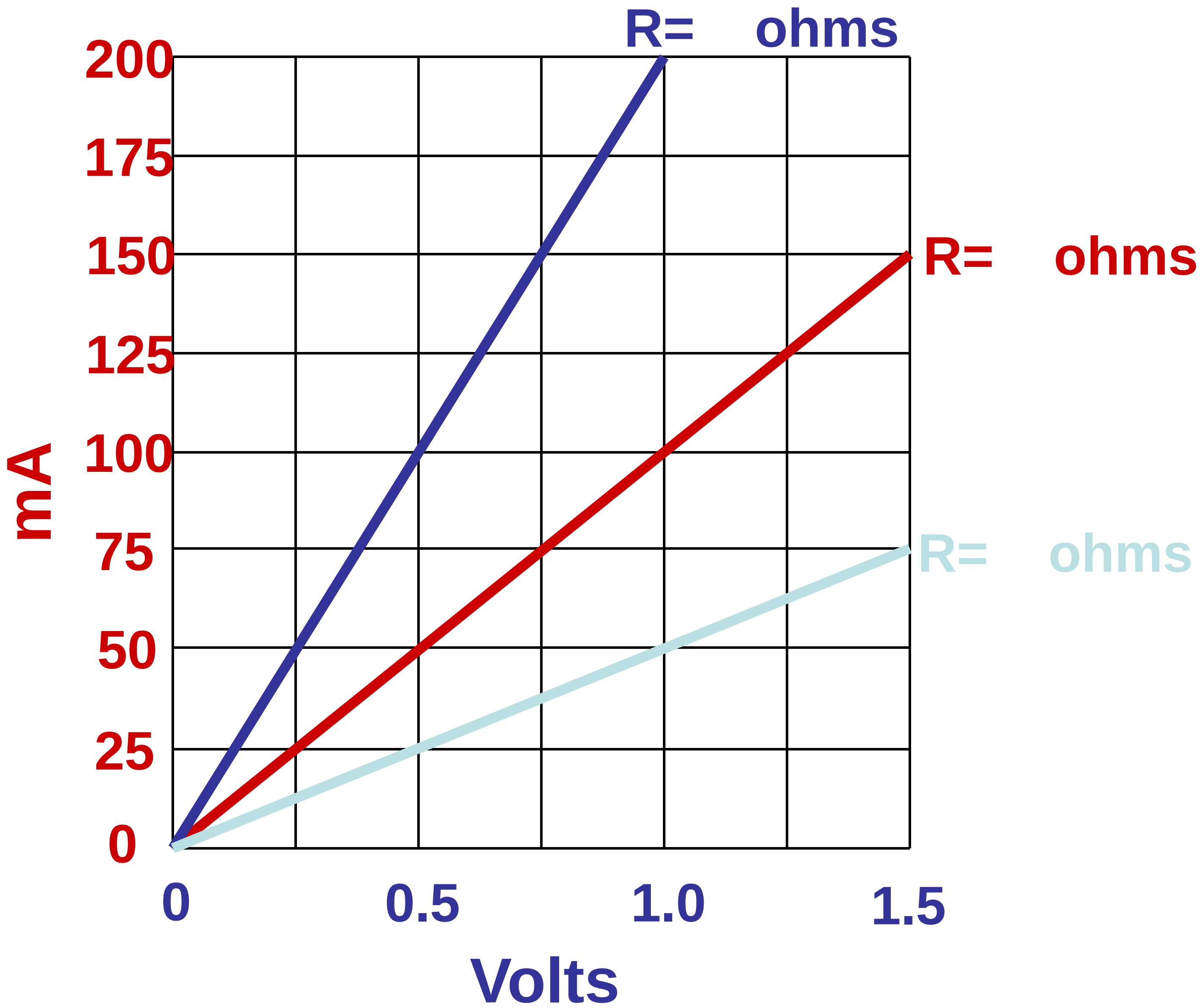


The carriers move away from the junction.

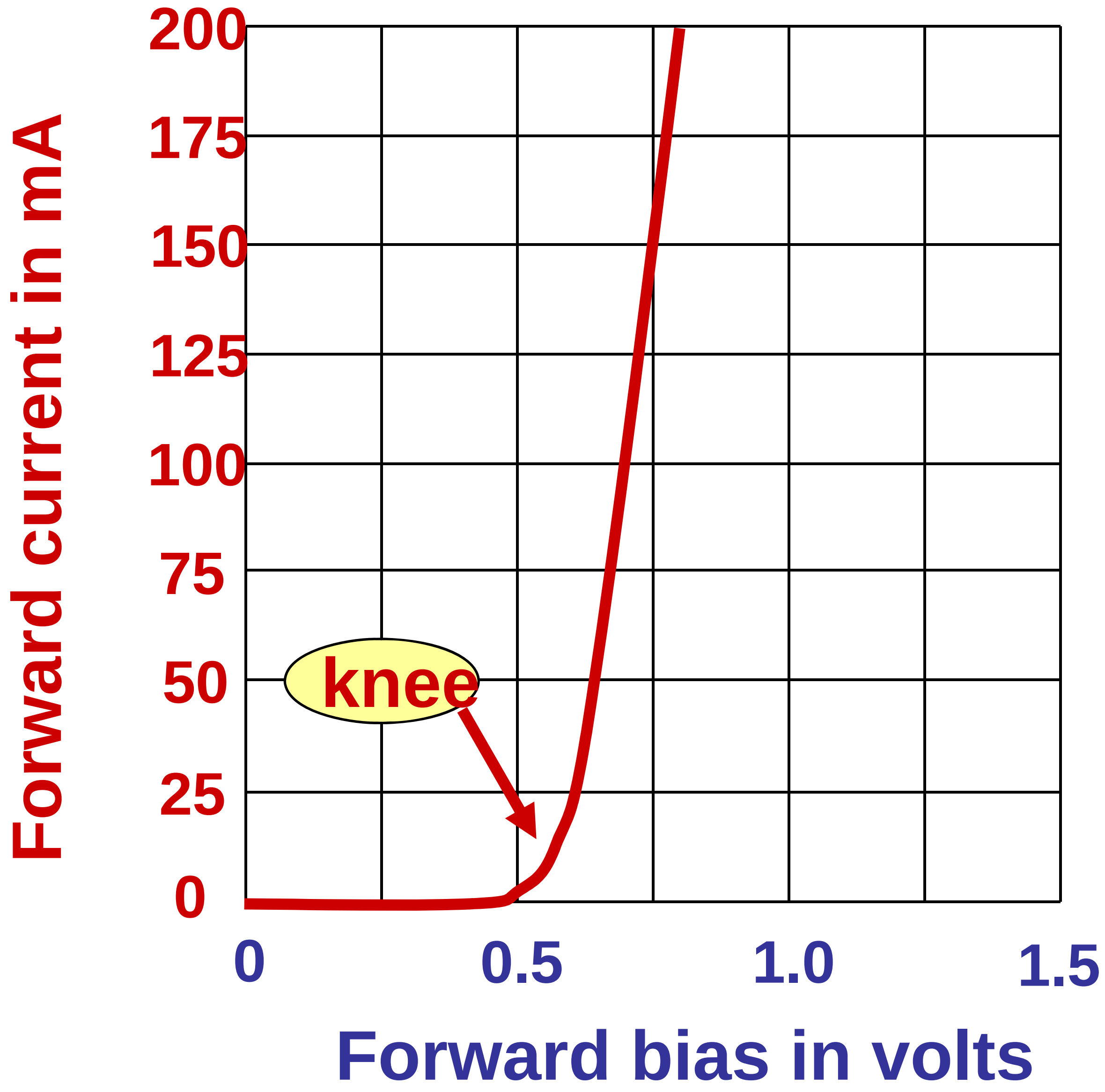
The depletion region is reestablished and the diode is off.

Knowledge Review

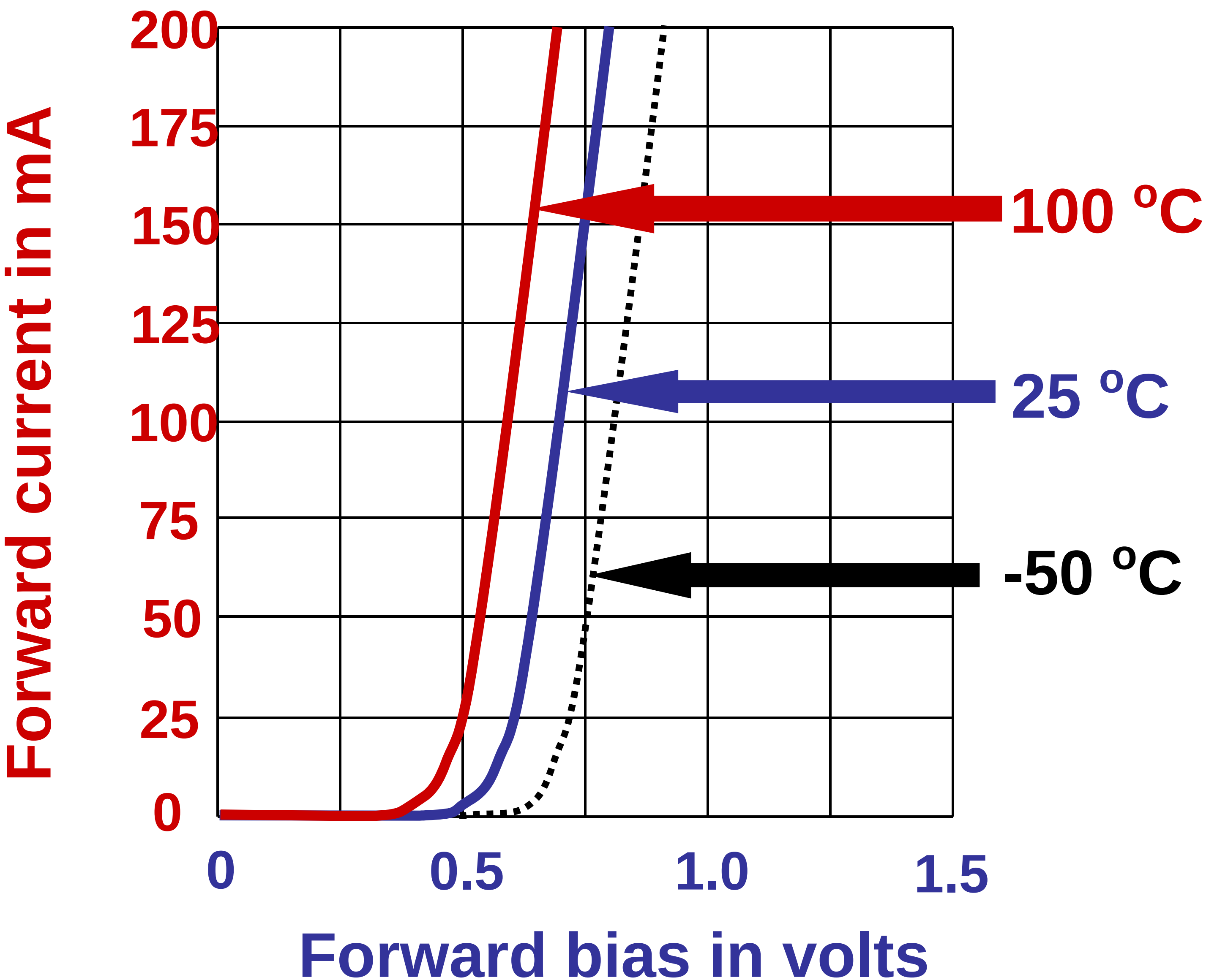
- The volt-ampere graph for a resistor is a straight line (a resistor is a linear device).
- The volt-ampere graph for a diode is non-linear.
- The knee voltage for a silicon diode is approximately 0.7 volts. This is the voltage required to collapse the depletion region.
- Excess reverse bias will result in diode breakdown.
- The cathode end might be marked with a band.
- Diodes can be tested with an ohmmeter.



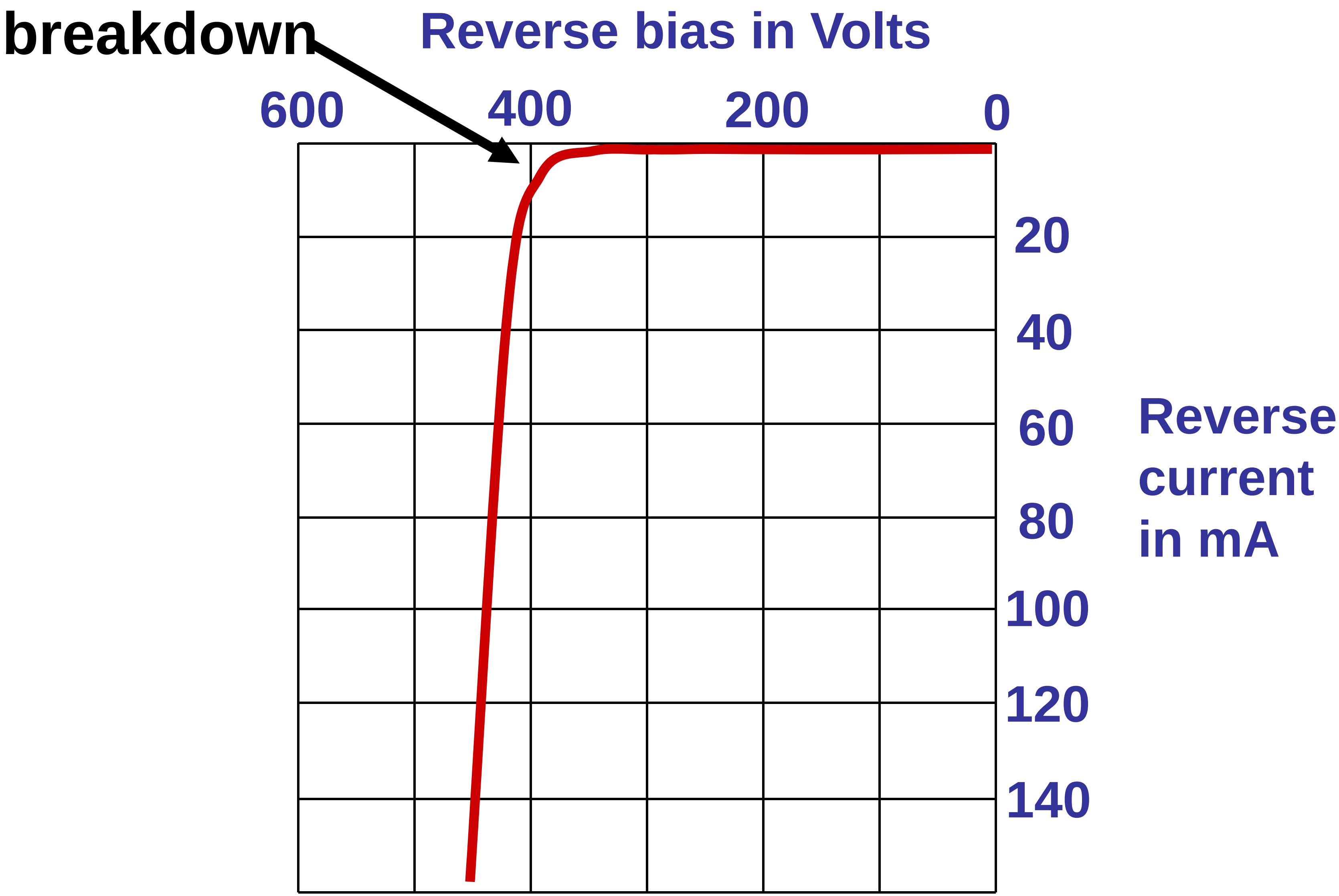
Resistor volt-ampere characteristic curves



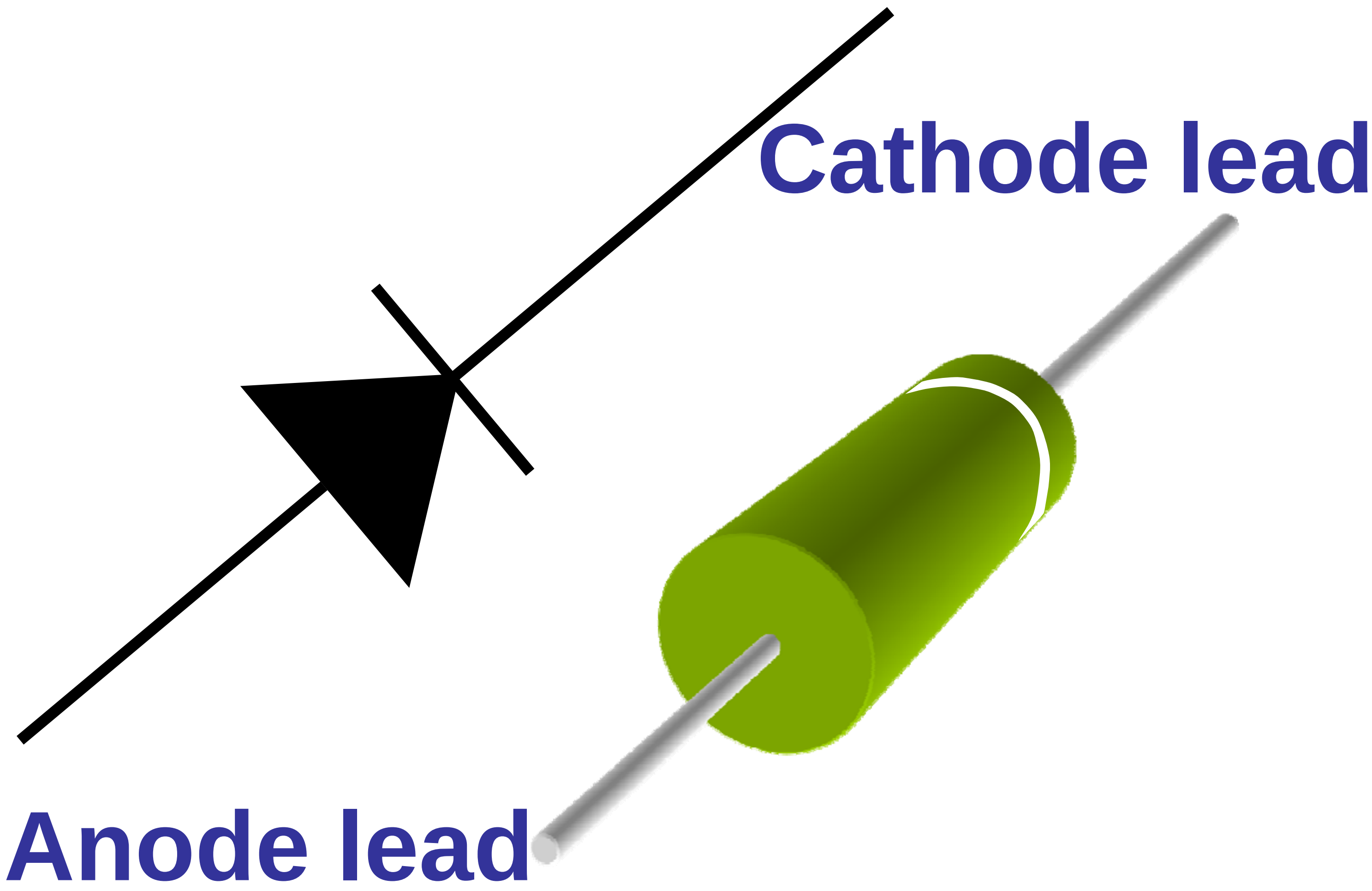
Silicon diode volt-ampere characteristic curve

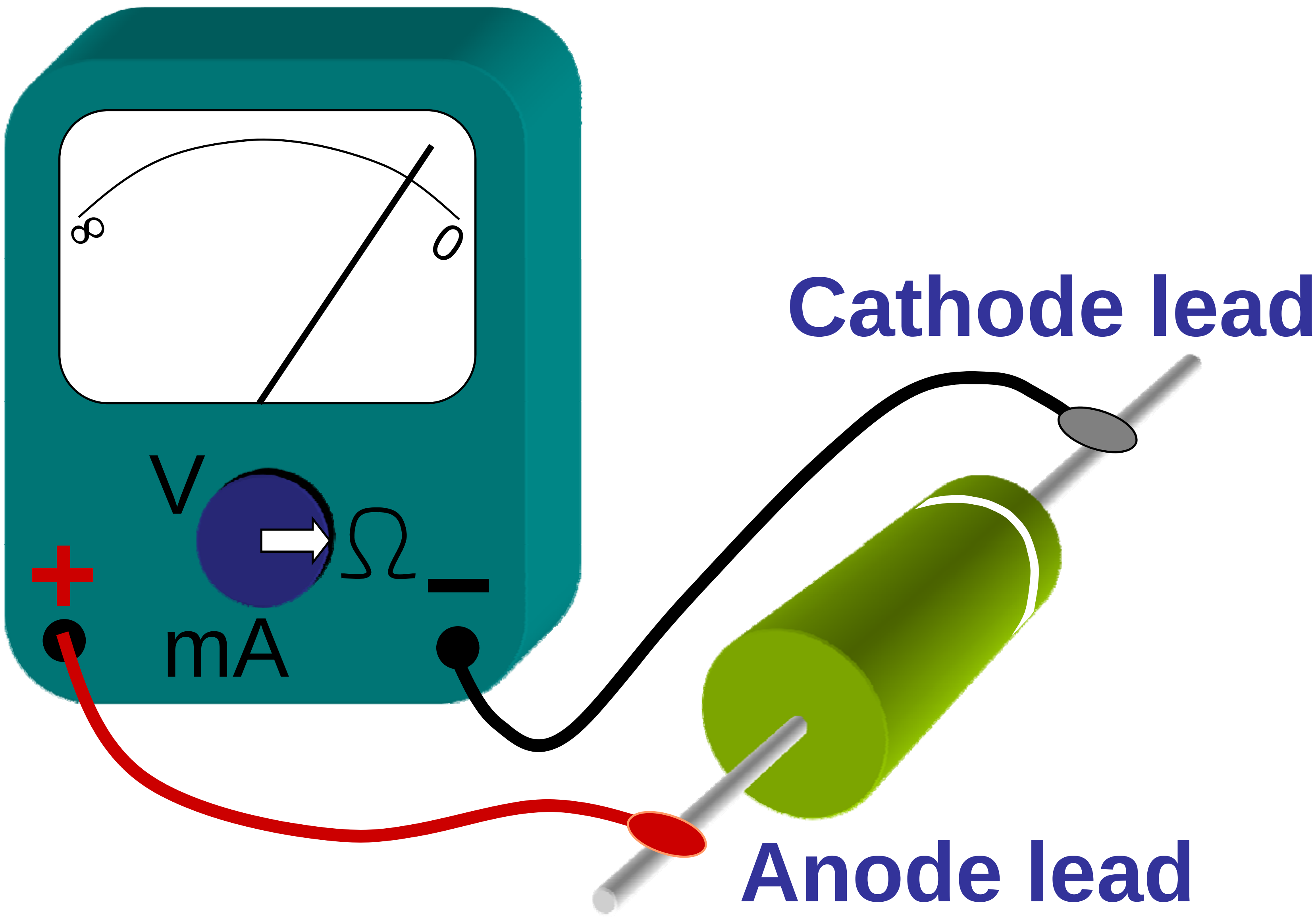


The effect of temperature

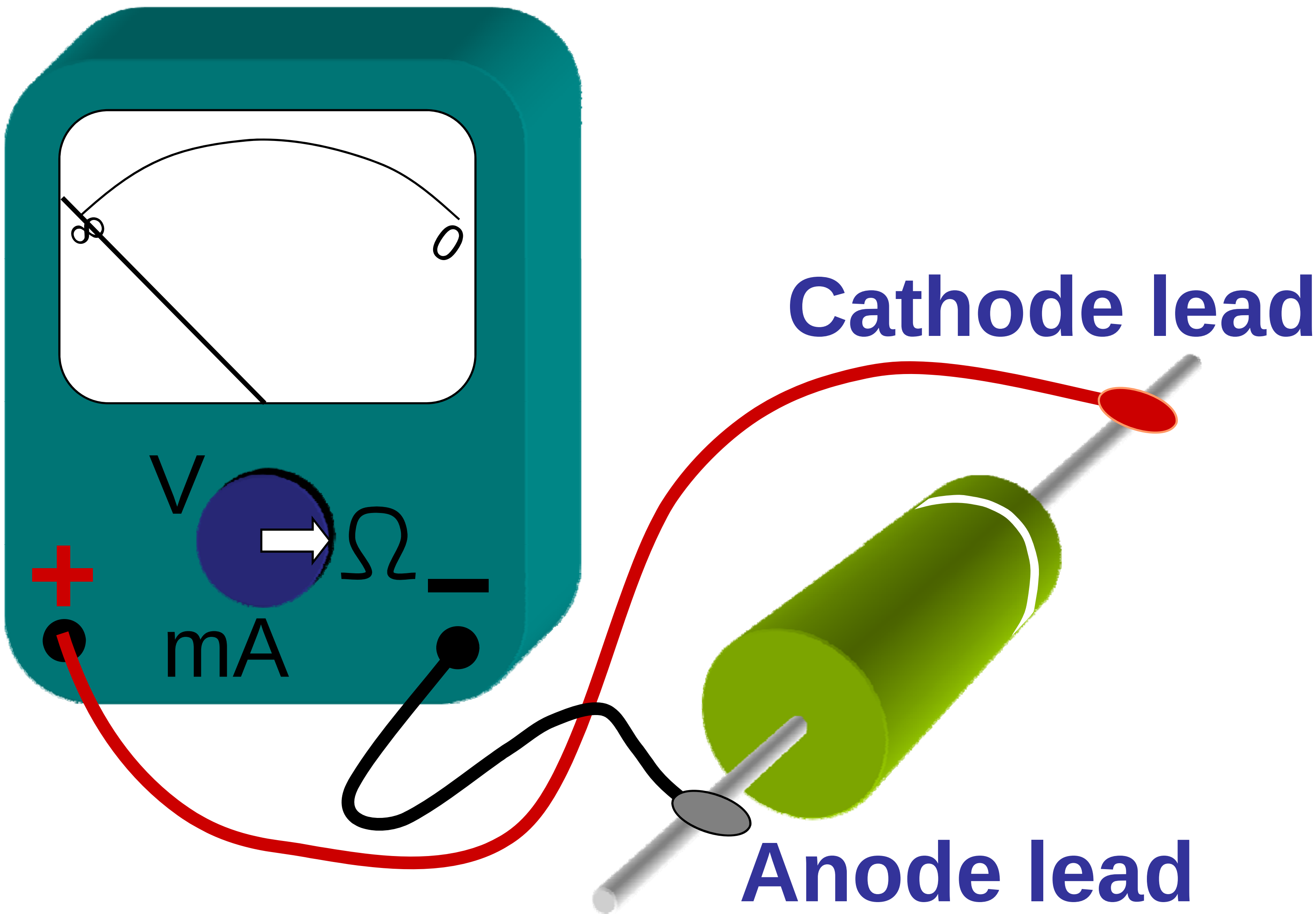


Silicon diode reverse bias characteristic curve


Cathode lead
Anode lead



The diode is forward biased by the ohmmeter.

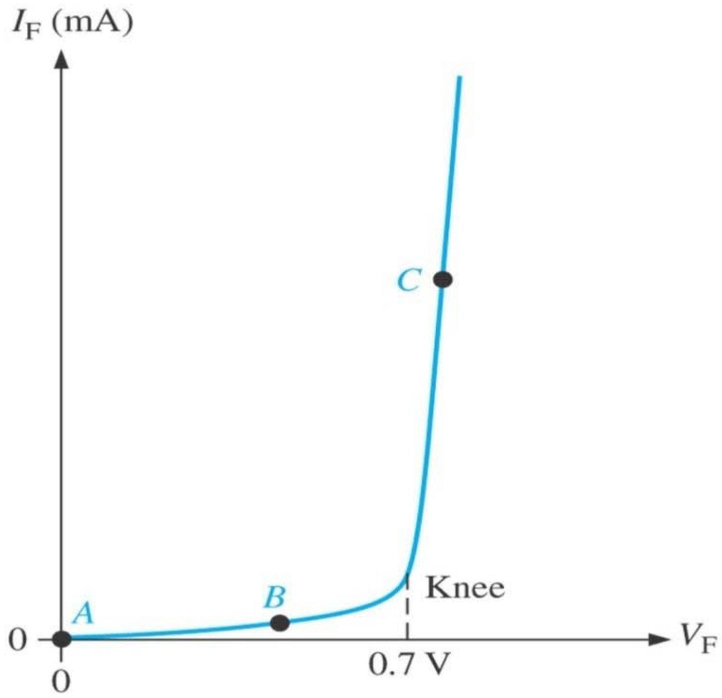


The diode is reverse biased by the ohmmeter.

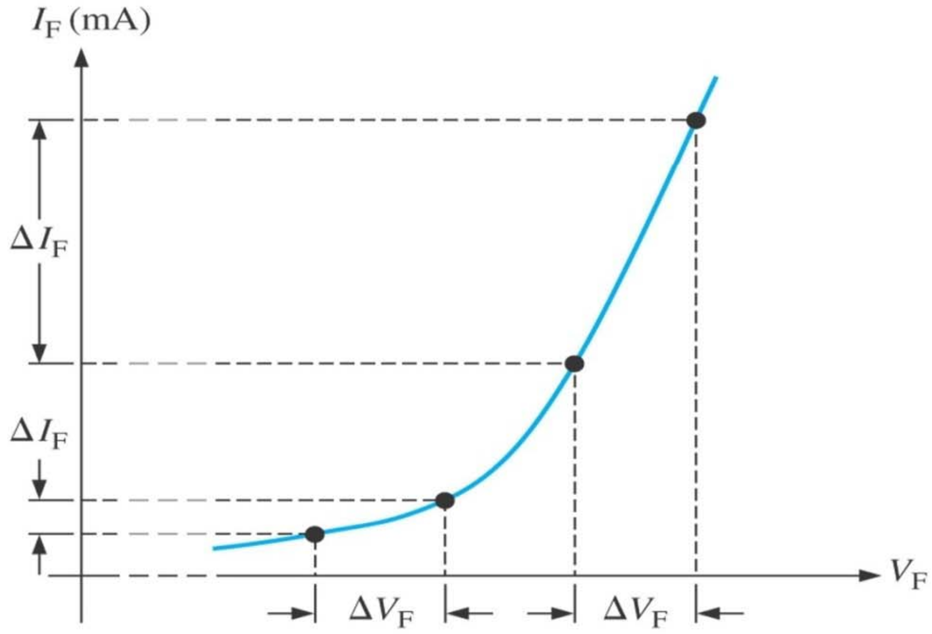
Diode Testing with Ohmmeter

- **Low resistance in both directions: the diode is shorted.**
- **High resistance in both directions: the diode is open.**
- **Relatively low resistance in the reverse direction: the diode is leaky.**
- **The ratio of reverse resistance to forward resistance is > 1000: the diode is good.**

V and I in a forward biased diode

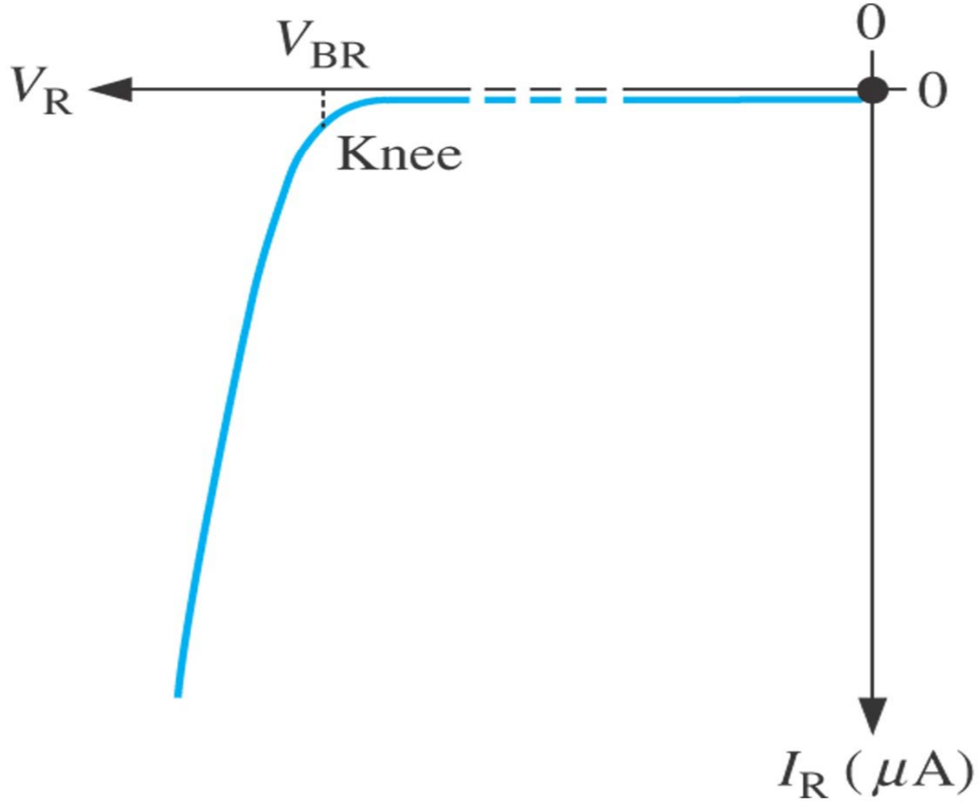


(a) *V-I* characteristic curve for forward bias.

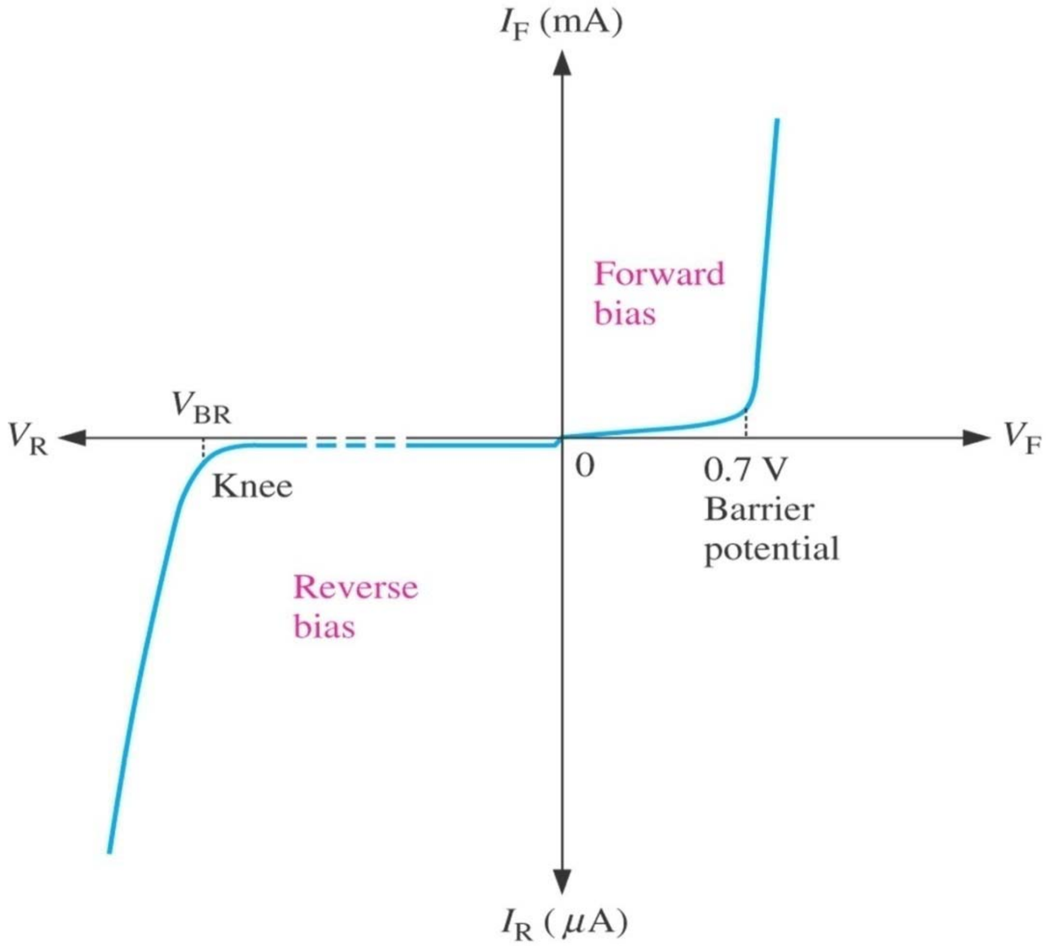


(b) Expanded view of a portion of the curve in part (a). The dynamic resistance r'_d decreases as you move up the curve, as indicated by the decrease in the value of $\Delta V_F / \Delta I_F$.

V and I in a reverse biased diode



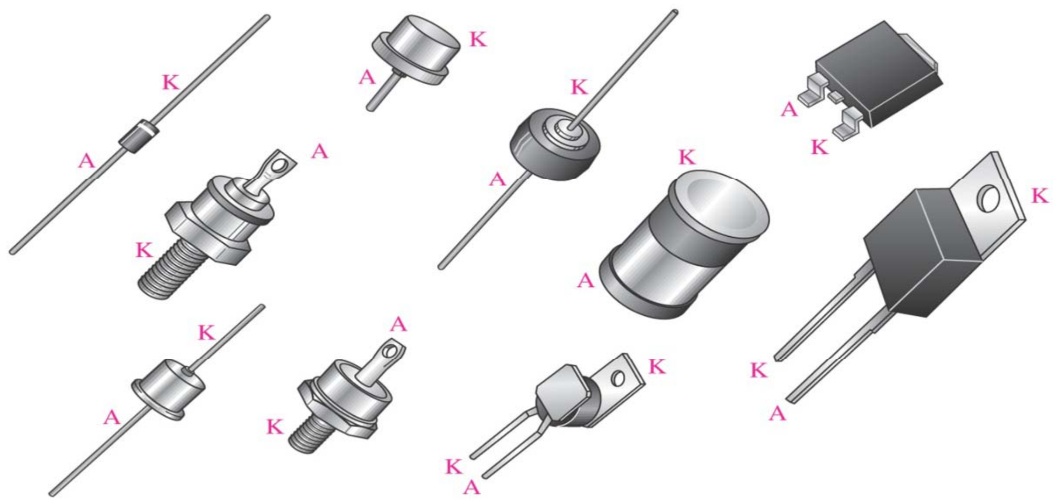
The complete V-I Characteristic



Diode schematic symbol, packaging

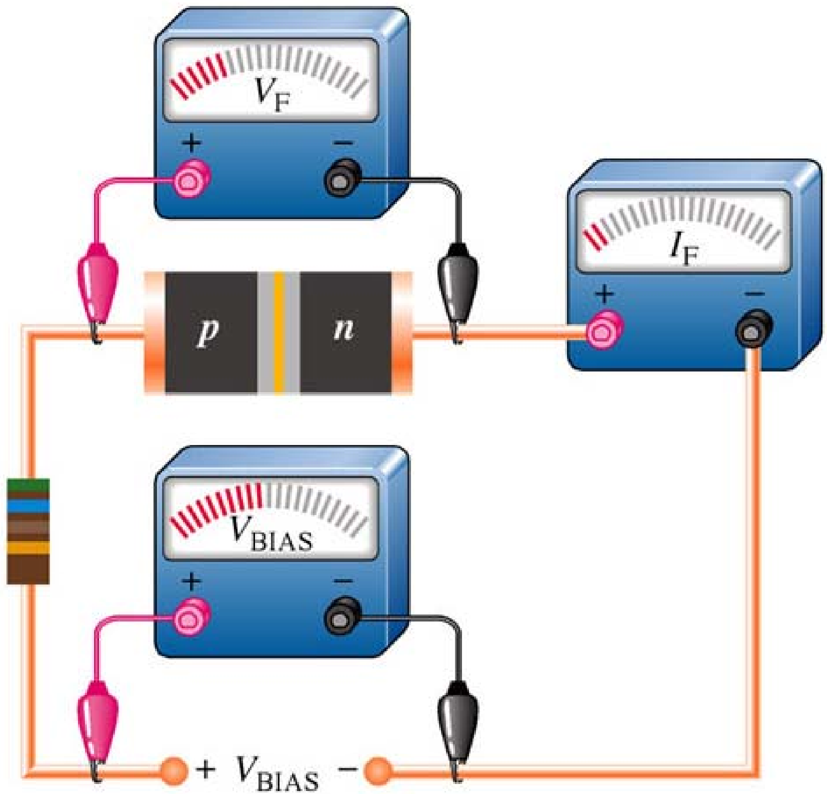
(a) Basic diode structure

(b) Schematic symbol



Forward bias testing(1)

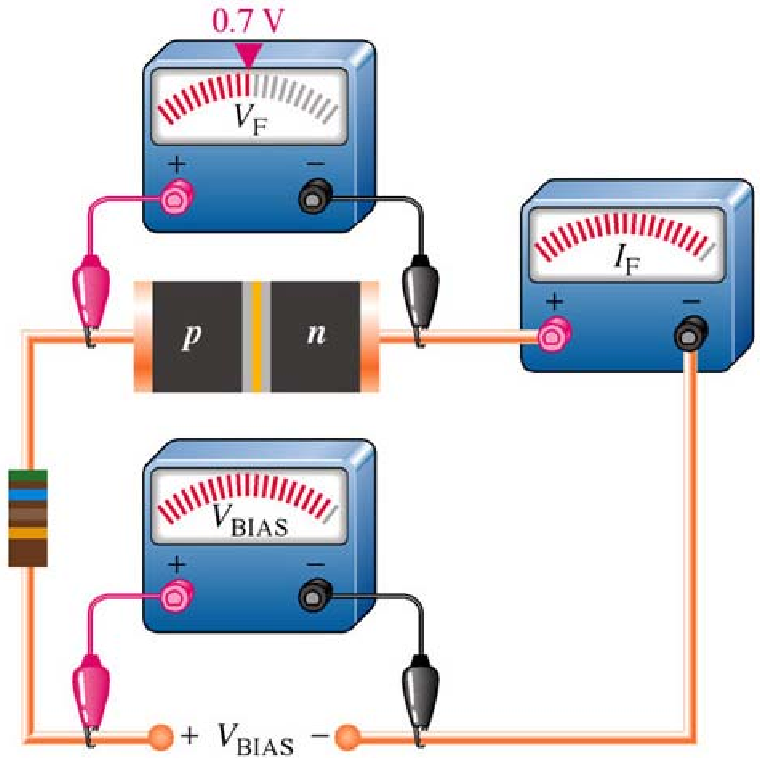
In this case with the voltage applied is less than the barrier potential so the diode for all practical purposes is still in a non-conducting state. Current is very small.



(a) Small forward-bias voltage ($V_F < 0.7$ V), very small forward current.

Forward bias testing(2)

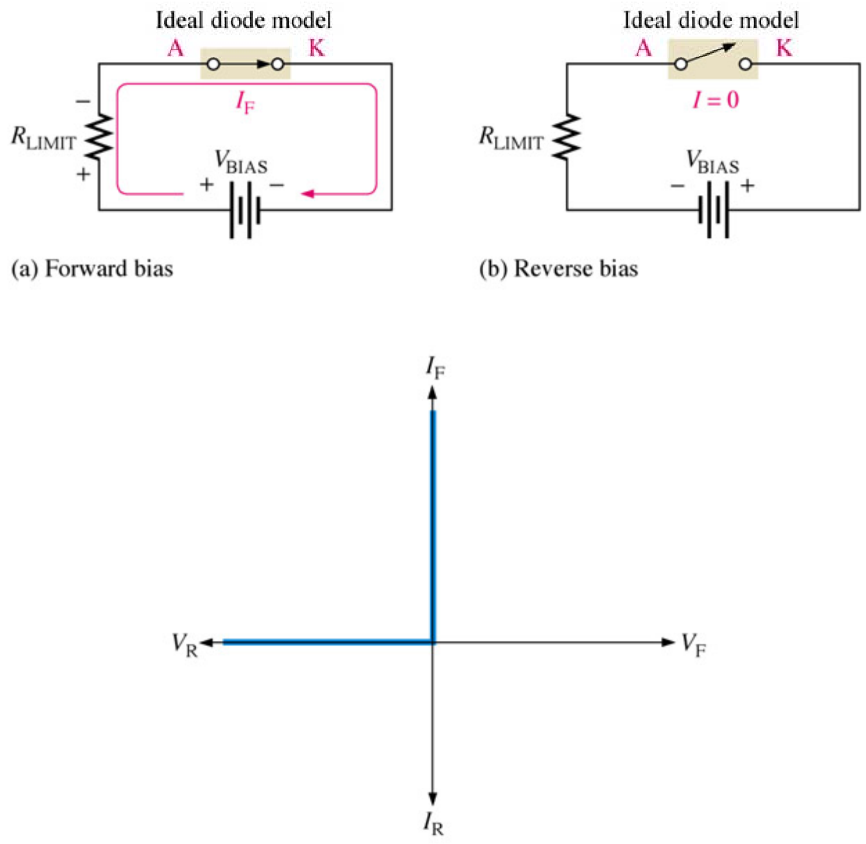
With the applied voltage exceeding the barrier potential the now fully forward-biased diode conducts. Note that the only practical loss is the .7 Volts dropped across the diode.



(b) Forward voltage reaches and remains at approximately 0.7 V. Forward current continues to increase as the bias voltage is increased.

Ideal diode V-I characteristic curve

In this characteristic curve we do not consider the voltage drop or the resistive properties. Current flow proportionally increases with voltage.

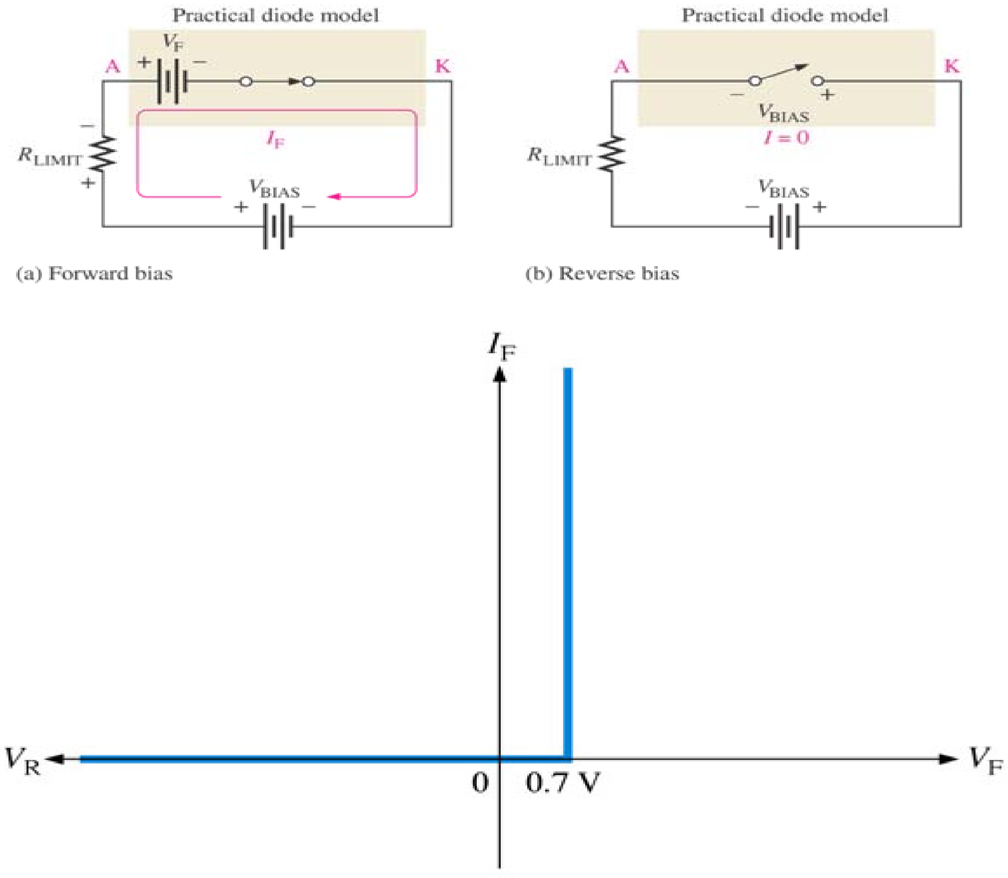


(c) Ideal characteristic curve (blue)

Note. Diode acts as an ideal switch

Practical diode V-I characteristic curve

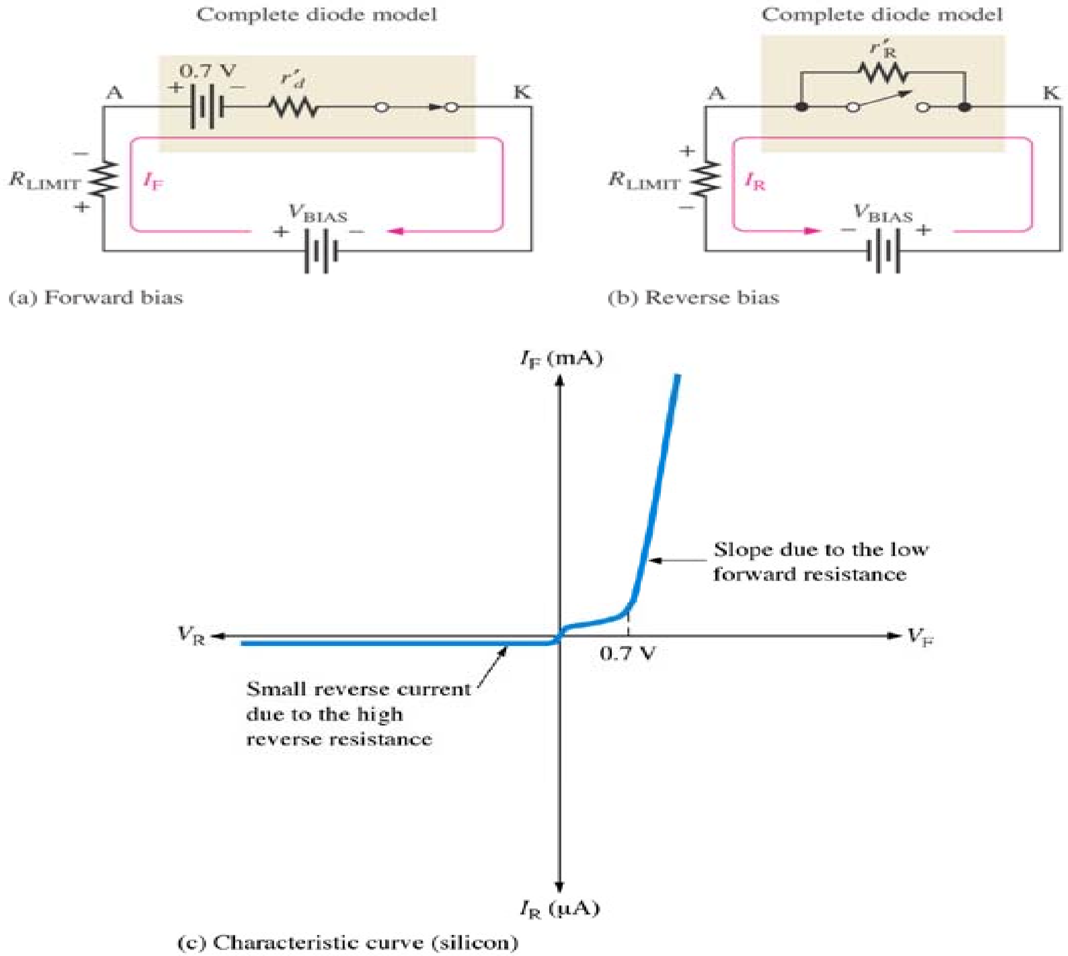
In most cases we consider only the forward bias voltage drop of a diode. Once this voltage is overcome the current increases proportionally with voltage.This drop is particularly important to consider in low voltage applications.



(c) Characteristic curve (silicon)

Complex V-I characteristic curve

The voltage drop is not the only loss of a diode. In some cases we must take into account other factors such as the resistive effects as well as reverse breakdown.

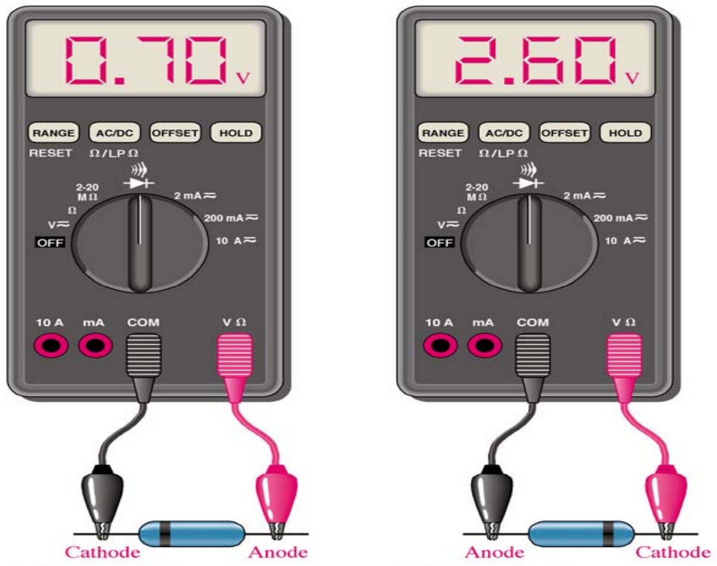


Troubleshooting Diodes (multimeter with diode testing function)

Testing a diode is quite simple, particularly if the multimeter used has a diode check function. With the diode check function a specific known voltage is applied from the meter across the diode.

With the diode check function a good diode will show approximately .7 V or .3 V when forward biased.

When checking in reverse bias the full applied testing voltage will be seen on the display. Note some meters show an infinite (blinking) display.



(a) Forward-bias test
(b) Reverse-bias test

Troubleshooting Diodes (multimeter setting as ohmmeter)

An ohmmeter can be used to check the forward and reverse resistance of a diode if the ohmmeter has enough voltage to force the diode into conduction. Of course, in forward-biased connection, low resistance will be seen and in reverse-biased connection high resistance will be seen.

Open and Shorted Diode

Open Diode

In the case of an *open diode* no current flows in either direction which is indicated by the full checking voltage with the diode check function or high resistance using an ohmmeter in both forward and reverse connections.

Shorted Diode

In the case of a *shorted diode* maximum current flows indicated by a 0 V with the diode check function or low resistance with an ohmmeter in both forward and reverse connections.

Summary

- Diodes, transistors, and integrated circuits are all made of semiconductor material.
- P-materials are doped with trivalent impurities
- N-materials are doped with pentavalent impurities.
- P and N type materials are joined together to form a PN junction
- A diode is nothing more than a PN junction.
- At the junction a depletion region is formed. This creates barrier that requires approximately .3 V for a Germanium and .7 V for Silicon for conduction to take place.