EEE 1217
Analog Electronic Circuits

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PPT# 1: Semiconductor Diodes

EEE 1217: Analog Electronic Circuits

Credits: 3 Contact Hours: 3 Hrs/Week

Syllabus

- Introduction to Semiconductors: p-n junction diode characteristics; diode applications; half and full wave rectifier, regulated power supply using Zener diode; Bipolar transistor : operation principles, characteristics, FET: Introduction to JFET, MOSFET, NMOS, PMOS and CMOS; Biasing and application in switching circuits.
- BJT Small-signal low frequency h-parameter model, hybrid pie model, Amplifiers, Darlington pairs.
- Operational amplifiers: Linear application of Op-Amp, gain, input and output impedances, offset null adjustment, frequency response and noise. SCR, TRIAC, DIAC, UJT: characteristics and applications, Introduction to oscillator, rectifiers, active filters, regulated power supply, Stabilizer and UPS, Basic ideas about IC fabrication techniques

References

- **Electronic Devices and Circuit Theory by Robert L. Boylestad**
- **Principle of Electronics by V. K. Mehta**

Semiconductor Materials

- **Materials commonly used in the development of semiconductor devices**
  - **Silicon (Si)**
  - **Germanium (Ge)**
  - **Gallium Arsenide (GaAs)**

Doping

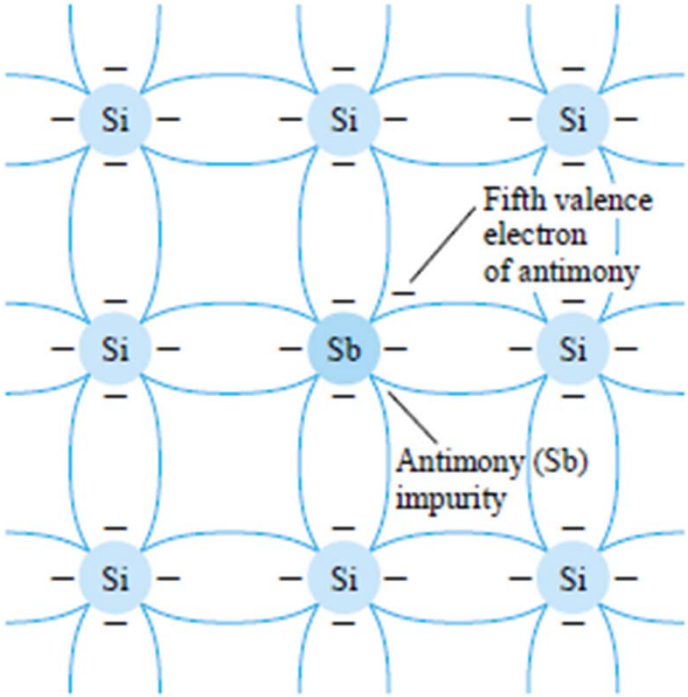
- The electrical characteristics of silicon and germanium are improved by adding materials in a process called doping.
- There are just two types of doped semiconductor materials
  - n-type
  - p-type
- n-type materials contain an excess of conduction band electrons.
- p-type materials contain an excess of valence band holes.

Majority and Minority Carriers

- **Two currents through a diode**
  - **Majority Carriers**
    - **The majority carriers in *n*-type materials are electrons.**
    - **The majority carriers in *p*-type materials are holes.**
  - **Minority Carriers**
    - **The minority carriers in n-type materials are holes.**
    - **The minority carriers in p-type materials are electrons.**

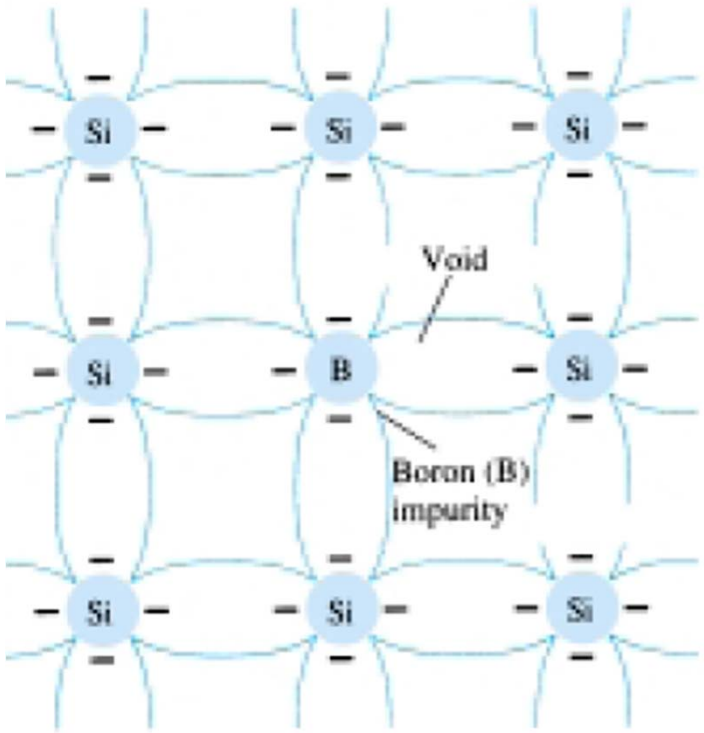
Extrinsic Materials (1/2)

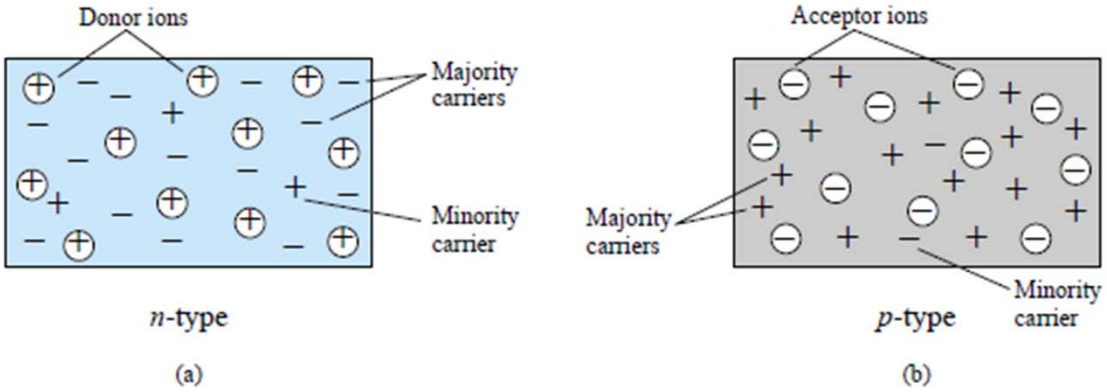
- A semiconductor material that has been subjected to the doping process is called an extrinsic material
- *n*-Type Material
  - **The n-type is created by introducing those impurity elements that have five valence electrons (pentavalent), such as antimony, arsenic, and phosphorus.**



Extrinsic Materials (2/2)

- **p-Type Material**
  - **The p-type material is formed by doping a pure germanium or silicon crystal with impurity atoms having three valence electrons**

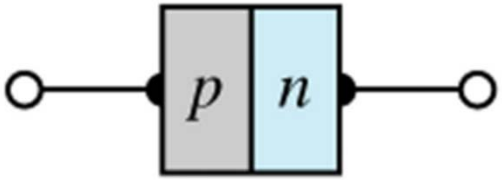




p-n Junctions

- **One end of a silicon or germanium crystal can be doped as a *p*-type material and the other end as an *n*-type material.**

- **The result is a *p-n* junction**

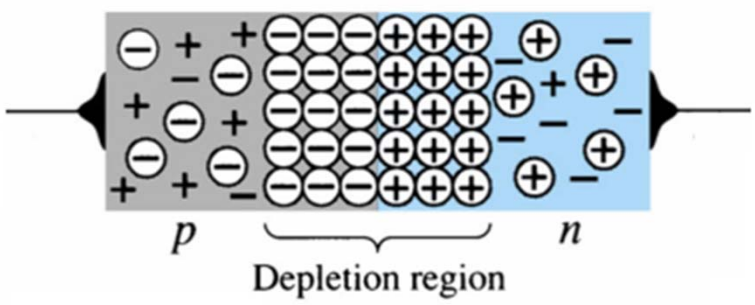


Formation of Depletion Layer

- **At the *p*-*n* junction, the excess conduction-band electrons on the *n*-type side are attracted to the valence-band holes on the *p*-type side.**

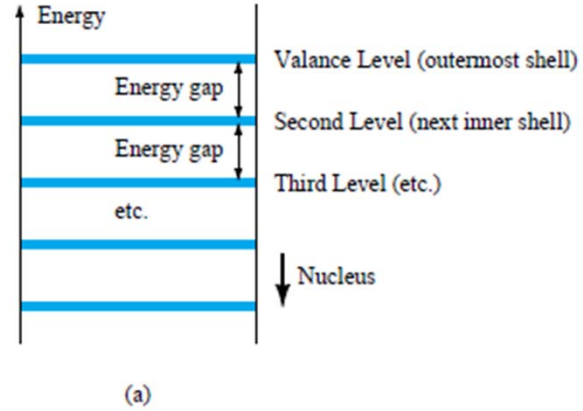
  The electrons in the *n*-type material migrate across the junction to the *p*-type material (electron flow).

- **The electron migration results in a negative charge on the p-type side of the junction and a positive charge on the n-type side of the junction.**



The result is the formation of a depletion region around the junction.

Energy Levels



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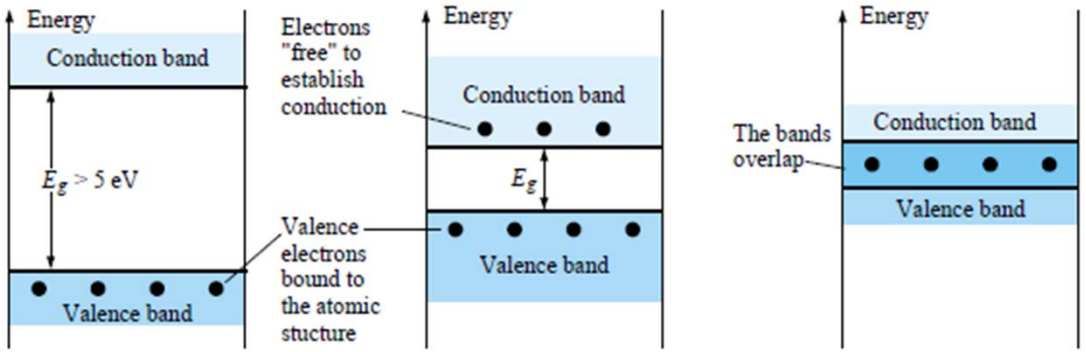

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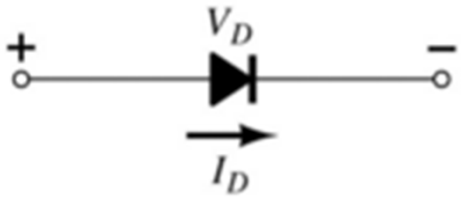
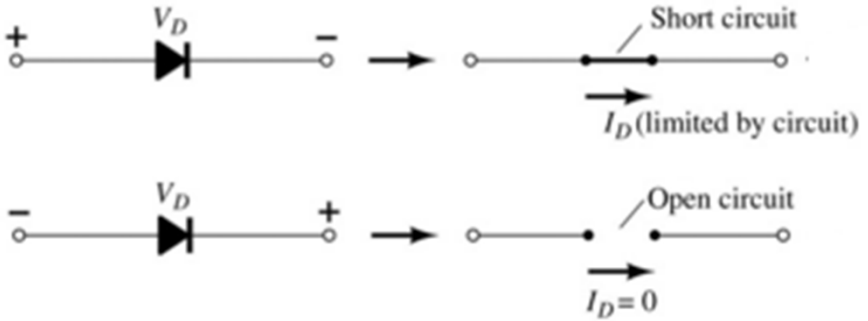
Diodes





The diode is a 2-terminal device.

A diode ideally conducts in only one direction.

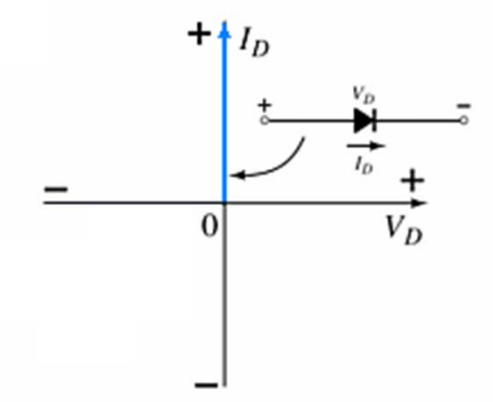
The ideal diode, therefore, is a short circuit for the region of conduction

The ideal diode, therefore, is an open circuit in the region of nonconduction.

Diode Characteristics

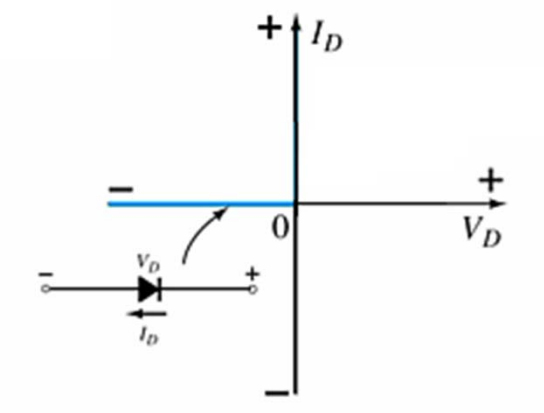
Conduction Region

- The voltage across the diode is 0 V
- The current is infinite
- The forward resistance is defined as $R_F = V_F / I_F$
- The diode acts like a short



Non-conduction Region

- All of the voltage is across the diode
- The current is 0 A
- The reverse resistance is defined as $R_R = V_R / I_R$
- The diode acts like open

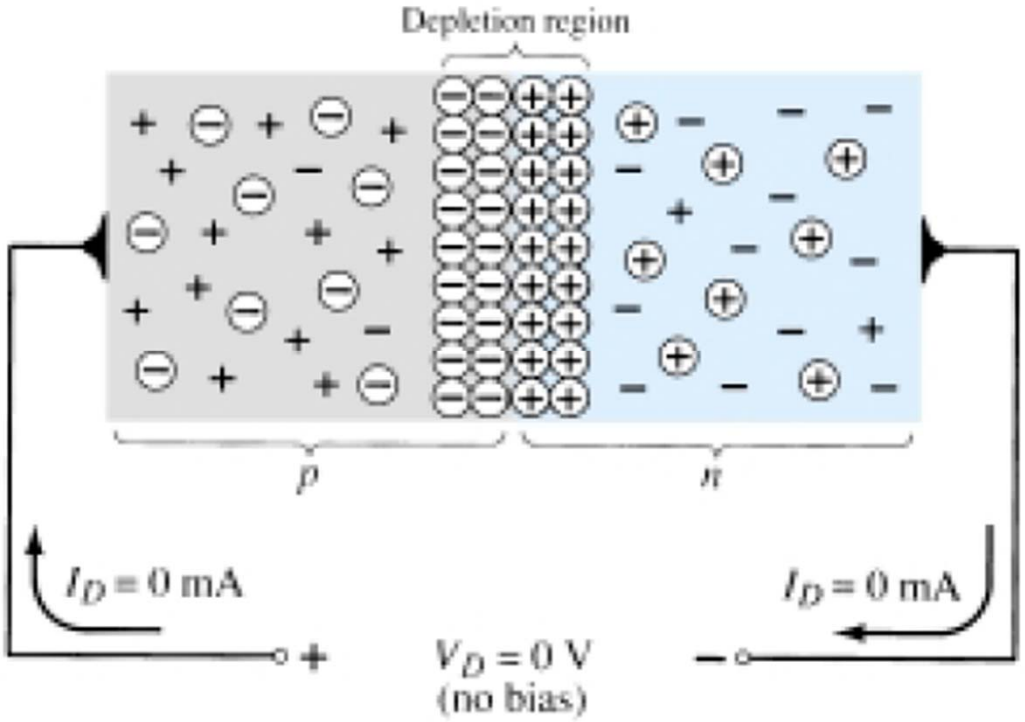


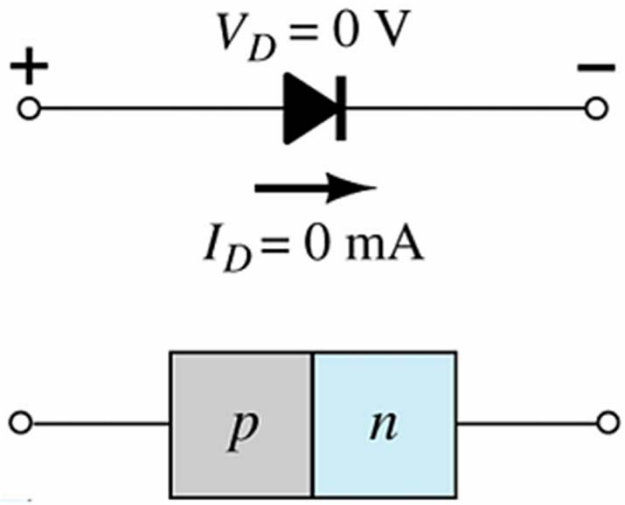
Diode Operating Conditions

- **A diode has three operating conditions**
  - **No bias**
  - **Forward bias**
  - **Reverse bias**

Diode Operating Conditions- No Bias

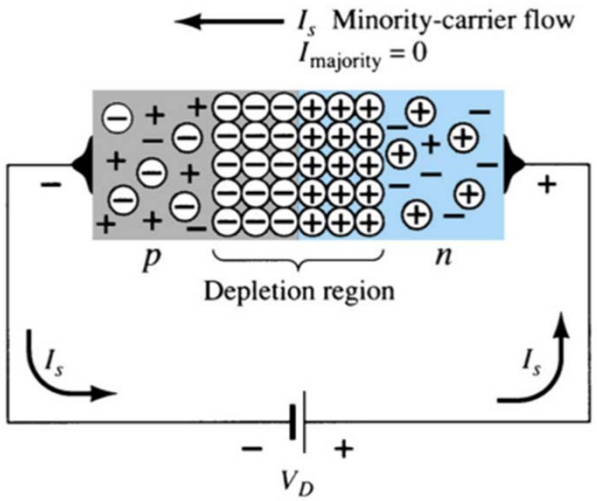
- No external voltage is applied: $V_D = 0$ V
- No current is flowing: $I_D = 0$ A
- Only a modest depletion region exists

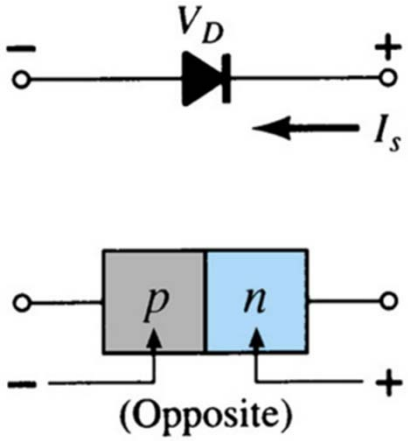




Diode Operating Conditions- Reverse Bias

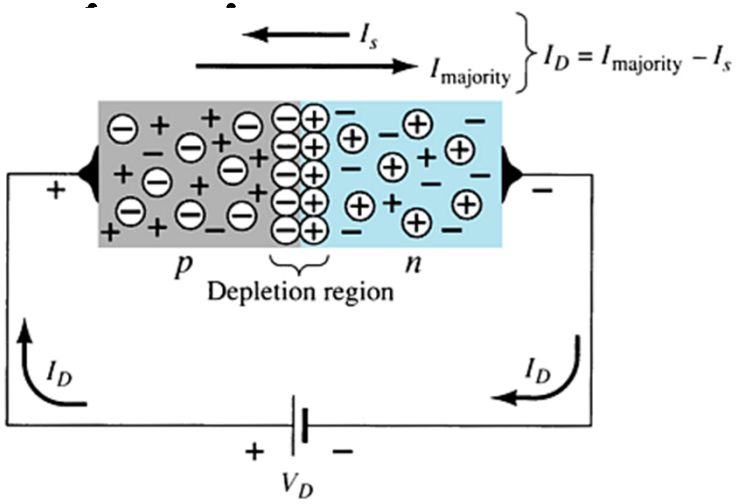
- External voltage is applied across the *p*-*n* junction in the opposite polarity of the *p*- and *n*-type materials.
- The reverse voltage causes the depletion region to widen.
- The electrons in the *n*-type material are attracted toward the positive terminal of the voltage source.
- The holes in the *p*-type material are attracted toward the negative terminal of the voltage source.

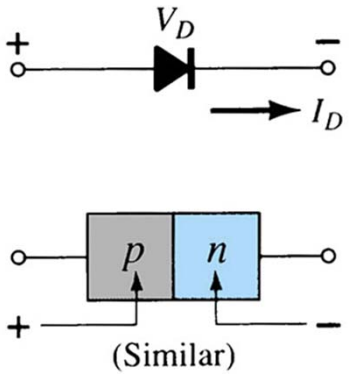




Diode Operating Conditions- Forward Bias

- **External voltage is applied across the *p*-*n* junction in the same polarity as the *p*- and *n*-type materials.**
- **The forward voltage causes the depletion region to narrow**
- **The electrons and holes are pushed toward the *p*-*n* junction**
- **The electrons and holes have sufficient energy to cross the *p*-**

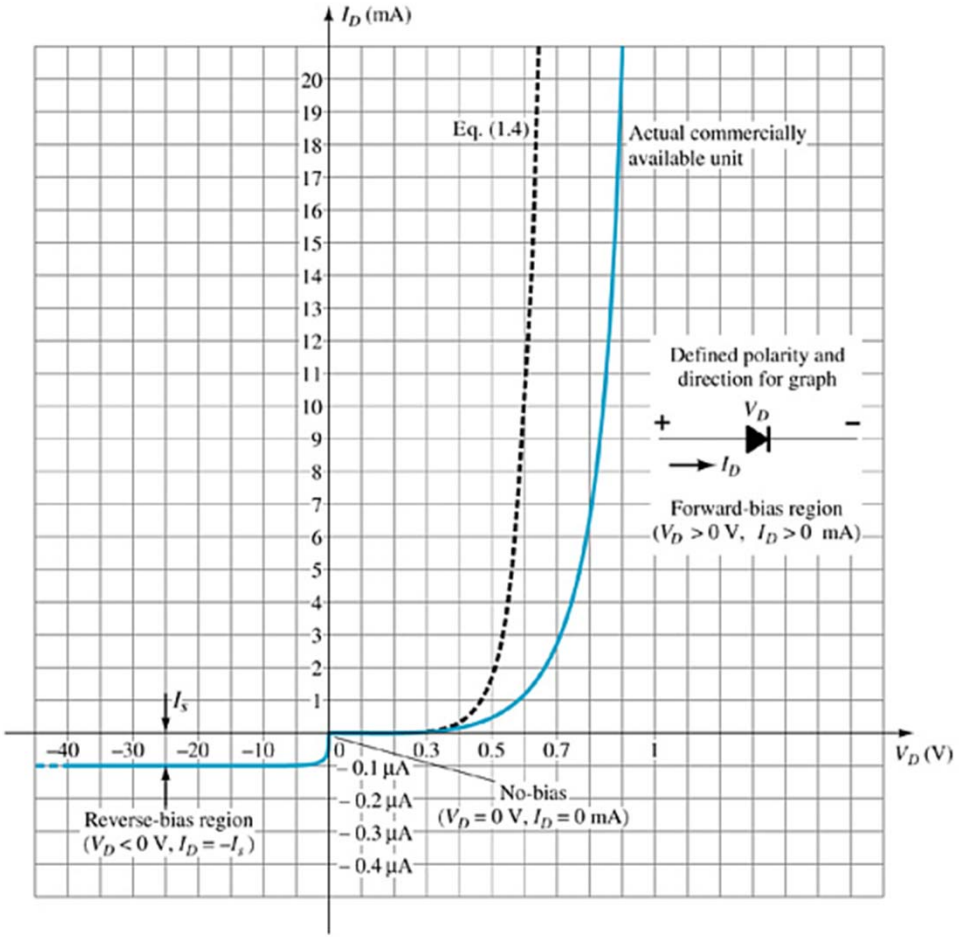




Actual Diode Characteristics

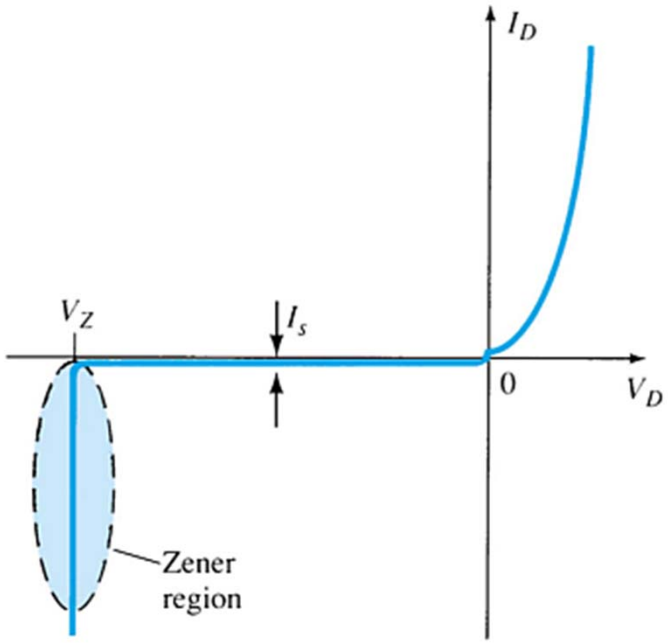
- **Note the regions for no bias, reverse bias, and forward bias conditions.**

- **Carefully note the scale for each of these conditions.**



Zener Region

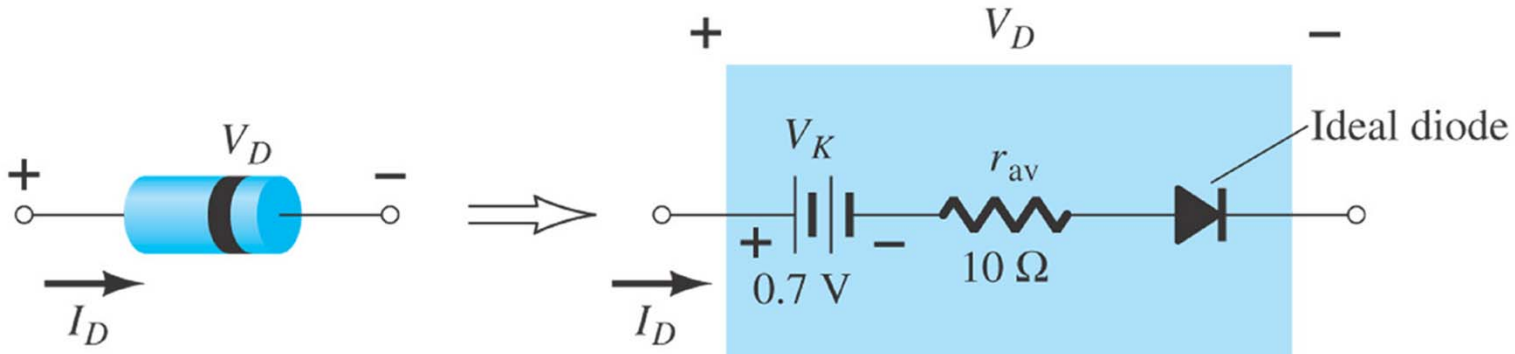
- **The Zener region is in the diode's reverse-bias region.**
- **At some point the reverse bias voltage is so large the diode breaks down and the reverse current increases dramatically**
- **The maximum reverse-bias potential that can be applied before entering the Zener region is called the peak inverse voltage (referred to simply as the PIV rating) or the peak reverse voltage (denoted by PRV rating).**
- **The voltage that causes a diode to enter the zener region of operation is called the zener voltage (V_Z).**



Forward Bias Voltage

- **The point at which the diode changes from no-bias condition to forward-bias condition occurs when the electrons and holes are given sufficient energy to cross the *p-n* junction. This energy comes from the external voltage applied across the diode.**
- **The forward bias voltage required for a**
  - **gallium arsenide diode ≅ 1.2 V**
  - **silicon diode ≅ 0.7 V**
  - **germanium diode ≅ 0.3 V**

Diode Equivalent Circuit

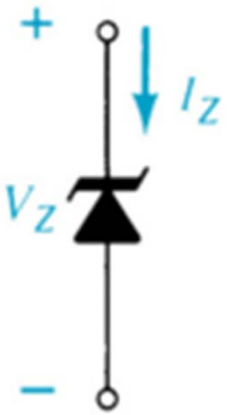


Diode Specification Sheets

1. **Forward Voltage (V_F) at a specified current and temperature**
2. **Maximum forward current (I_F) at a specified temperature**
3. **Reverse saturation current (I_R) at a specified voltage and temperature**
4. **Reverse voltage rating, PIV or PRV or V(BR), at a specified temperature**
5. **Maximum power dissipation at a specified temperature**
6. **Capacitance levels**
7. **Reverse recovery time, t_{rr}**
8. **Operating temperature range**

Zener Diode

- **A Zener is a diode operated in reverse bias at the Zener voltage (V_Z).**
- **Common Zener voltages are between 1.8 V and 200 V**



Light-Emitting Diode (LED)

- An LED emits photons when it is forward biased
- These can be in the infrared or visible spectrum
- The forward bias voltage is usually in the range of 2 V to 3 V.