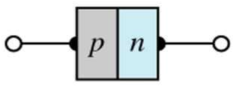
p-n Junctions

One end of an intrinsic semi-conductive materials can be doped as a *p*- type material and the other end as an *n*-type material.

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

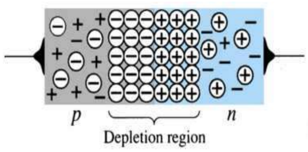


p-n Junctions

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).

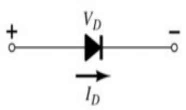
The electron migration results in a negative charge on the p-type side of the junction and a positive charge on the n-type side of the junction.



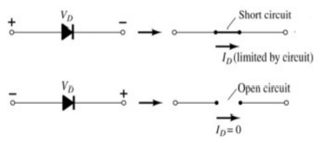
The result is the formation of a depletion region around the junction.

Diodes

The diode is a 2-terminal device.

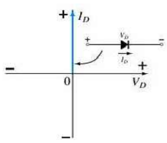


A diode ideally conducts in only one direction.



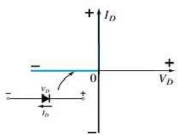
Diode Characteristics

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

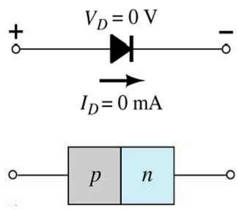
A diode has three operating conditions:

- No bias
- Forward bias
- Reverse bias

Diode Operating Conditions

No Bias

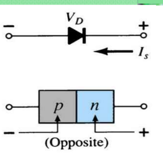
- No external voltage is applied: $V_D = 0$ V
- No current is flowing: $I_D = 0$ A
- Only a modest depletion region exists

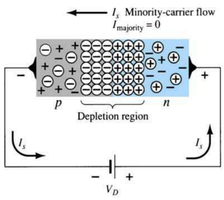


Diode Operating Conditions

Reverse Bias

External voltage is applied across the *p-n* junction in the opposite polarity of the *p-* and *n*-type materials.



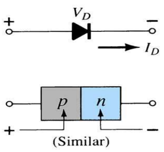


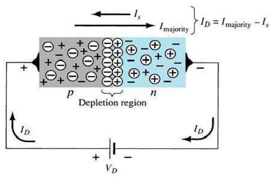
- The reverse voltage causes the depletion region to widen.
- The electrons in the *n*-type material are attracted toward the positive terminal of the voltage source.
- The holes in the *p*-type material are attracted toward the negative terminal of the voltage source.

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.



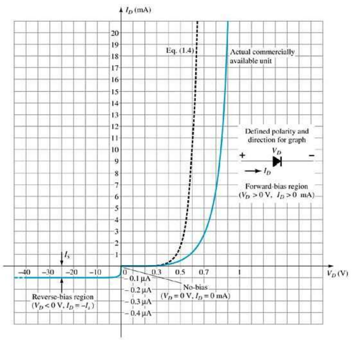


- The forward voltage causes the depletion region to narrow.
- The electrons and holes are pushed toward the *p-n* junction.
- The electrons and holes have sufficient energy to cross the *p-n* junction.

Actual Diode Characteristics

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

Carefully note the scale for each of these conditions.



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**

Temperature Effects

- As temperature increases it adds energy to the diode.
- It reduces the required forward bias voltage for forward- bias condition.
- It increases the amount of reverse current in the reverse- bias condition.
- It increases maximum reverse bias avalanche voltage.
- Germanium diodes are more sensitive to temperature variations than silicon or gallium arsenide diodes.

Resistance Levels

Semiconductors react differently to DC and AC currents.

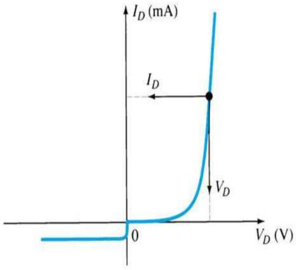
There are three types of resistance:

- **DC (static) resistance**
- **AC (dynamic) resistance**
- **Average AC resistance**

DC (Static) Resistance

For a specific applied DC voltage V_D, the diode has a specific current I_D, and a specific resistance R_D.

$$R_D = \frac{V_D}{I_D}$$



DC (Static) Resistance Example

Determine the dc resistance level when;

i. ID = 2 mA, VD = 0.5 V
ii. ID = 20 mA, VD = 0.8 V
iii. ID = - 1 µA , VD = -10 V