


EN1014



Electronic Engineering

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Department of ENT C

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Diodes and  
Diode Applications

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Main Topics

- Semiconductors for Electronic Devices
- Semiconductor Diodes
- Applications of Semiconductor Diodes

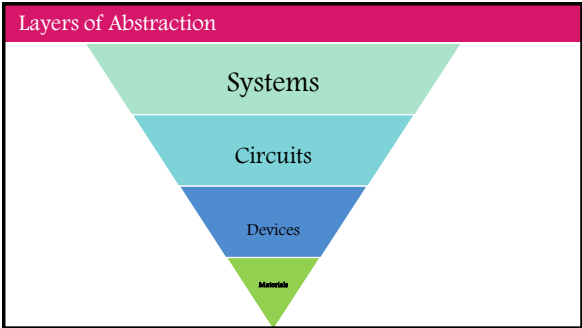
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Semiconductors for  
Electronic Devices

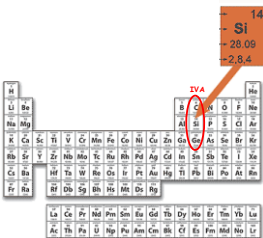
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INTRINSIC SEMICONDUCTORS



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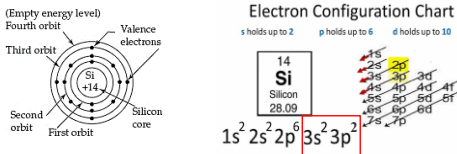
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## INTRINSIC SEMICONDUCTORS

- ☑ Pure Semiconductors
  - ☑ Not mixed(doped) with other materials
- ☑ Electrons and Holes are generated in pairs, due to thermal agitation even at room temperature
- ☑ Can carry a very small electric current using those free electrons and holes.

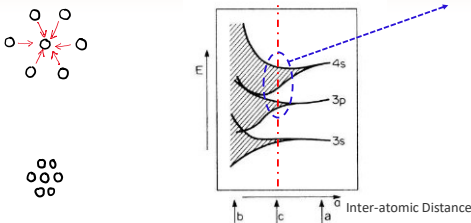
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## Energy Level Abstraction of Semiconductor Atoms



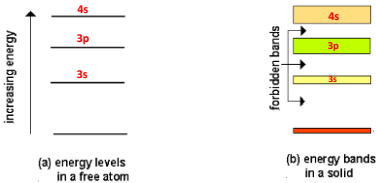
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## Energy Band Abstraction of Solids



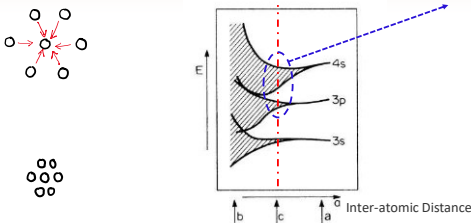
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## Energy Band Abstraction of Solids



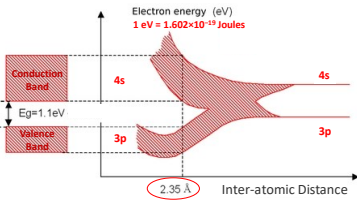
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## Upper Energy Bands of Silicon

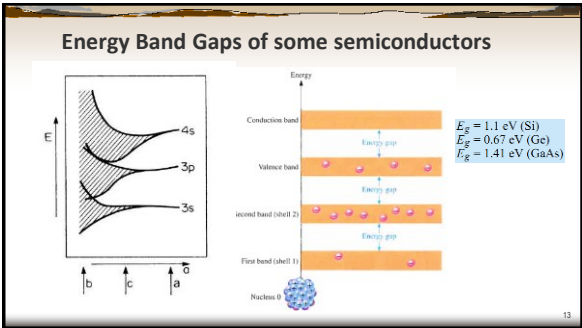


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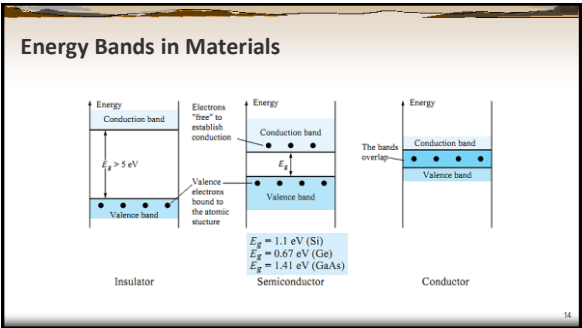
## Upper Energy Bands of Silicon



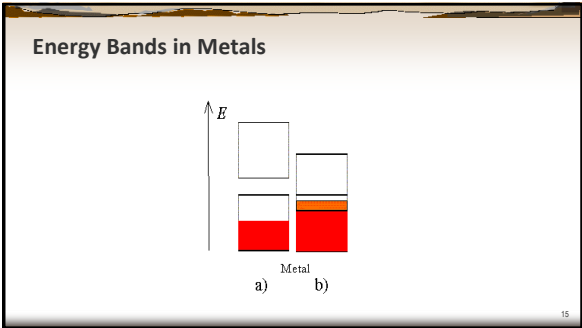
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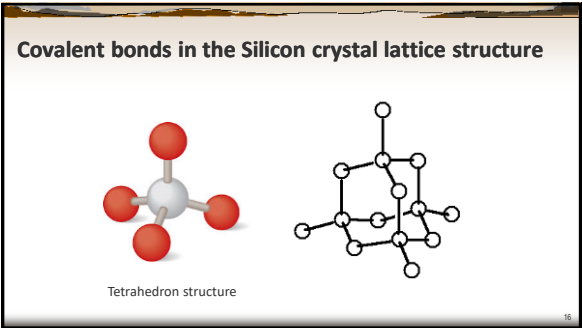
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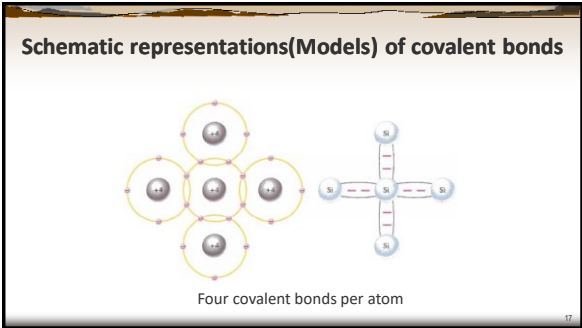
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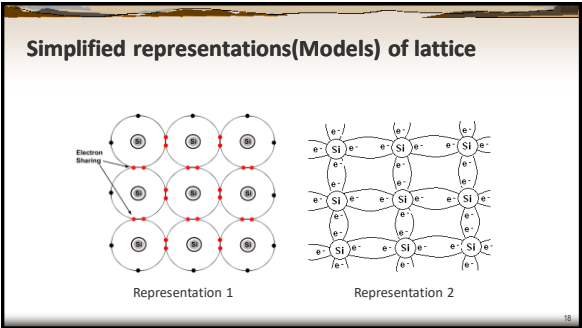
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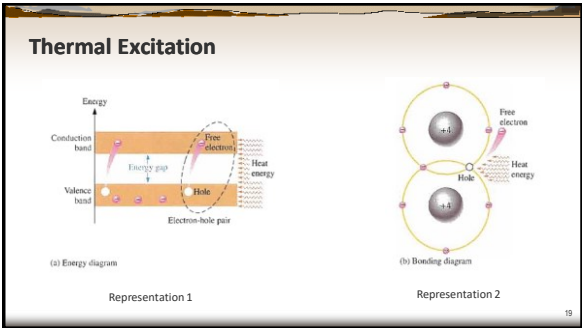
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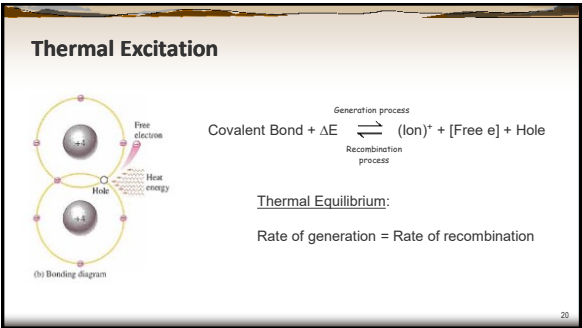
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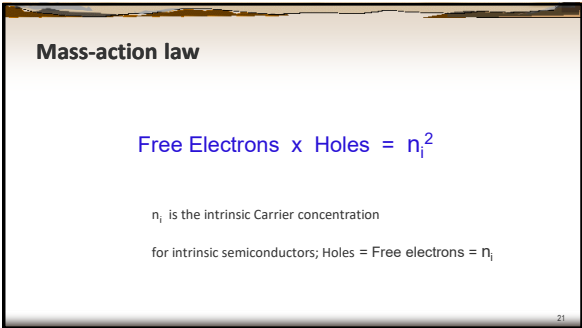
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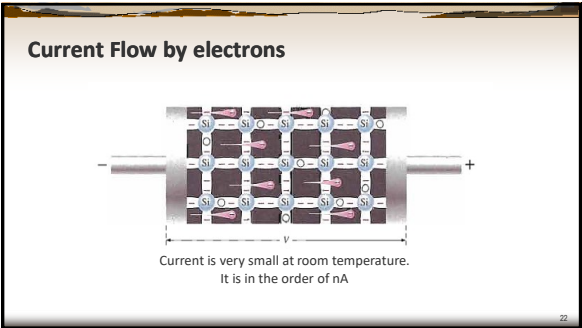
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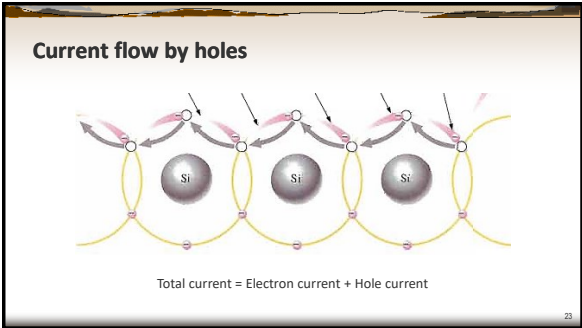
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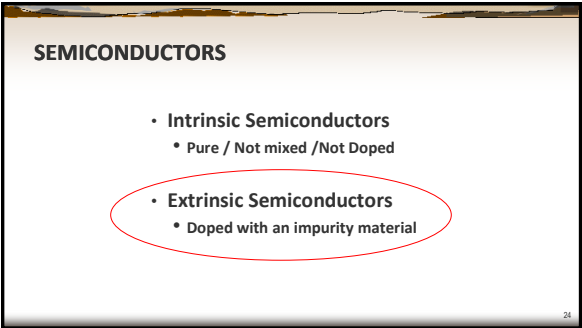
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**Making Extrinsic Semiconductors**

Group III A		Group V A	
5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	
13 Al Aluminium 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	
31 Ga Gallium 69.72	32 Ge Germanium 72.64	33 As Arsenic 74.92	
Trivalent		Pentavalent	

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**EXTRINSIC SEMICONDUCTORS**

- doped semiconductors
- p type – positive type  
majority holes  
minority electrons
- n type – negative type  
majority electrons  
minority holes

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**Making Extrinsic Semiconductors**

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**n – Type Semiconductor**

<https://www.youtube.com/watch?v=J8TEckh3t9Q>

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**Energy Levels due to Doping**

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**Current carriers**

Holes = All are thermally generated holes

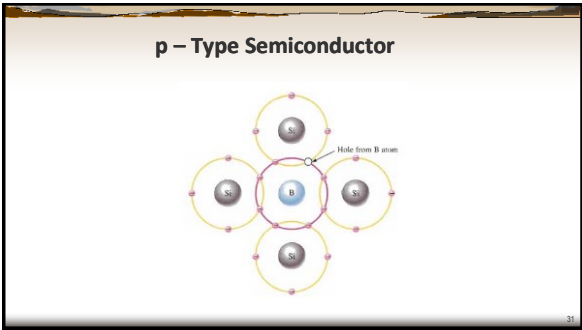
Free electrons = Donar donated electrons + Thermally generated electrons

Covalent Bond +  $\Delta E \rightleftharpoons (Ion)^+ + [Free\ electron] + Hole$

Holes decrease further in number.

At the new equilibrium state holes are minority carriers now.

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**Current carriers**

Free electrons = All are thermally generated holes

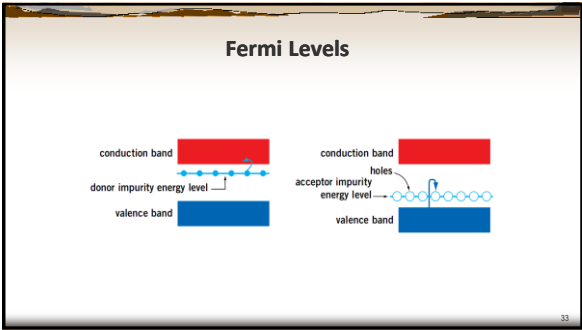
Holes = Acceptor associated holes + Thermally generated holes

Covalent Bond +  $\Delta E \rightleftharpoons (Ion)^+ + [Free\ electron] + Hole$

Free electrons decrease further in number.

At the new equilibrium state electrons are minority carriers now.

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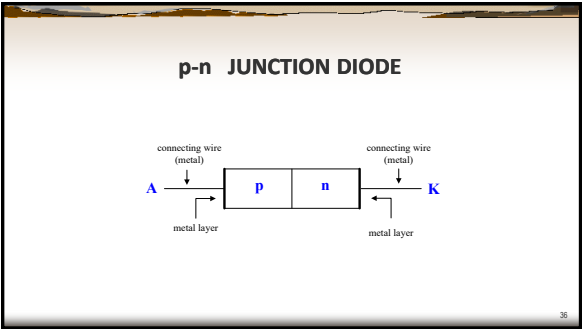
**Semiconductor Diodes**

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**SEMICONDUCTOR DIODES**

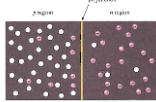
- 1) p-n junction diode
- 2) Forward biased diode
- 3) Reverse biased diode
- 4) V/I characteristics of the diode
- 5) The Ideal diode

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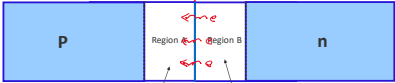


Diffusion Process

- Touching surfaces must be microscopically clean
- Electrons diffuse (spill over) from the border of the N material into the P material



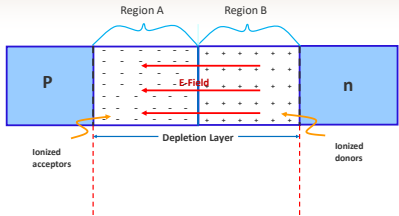
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Region A  
Acceptor atoms become negatively charged ions

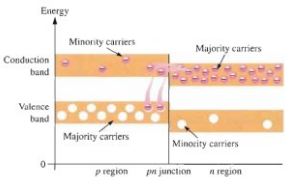
Region B  
Donor atoms become positively charged ions

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Energy Bands in p-n junction at the time of formation



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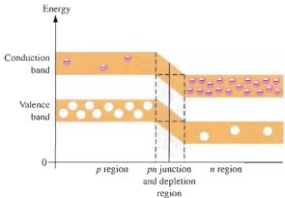
Depletion Layer

- ⇒ Width of these two regions(A & B) increase until they reach an equilibrium condition
  - Now just enough e's are on the P side to repel any more e's diffusion.
- ⇒ This double-layer of two opposite electric charges (+ and -) is called a Depletion layer.

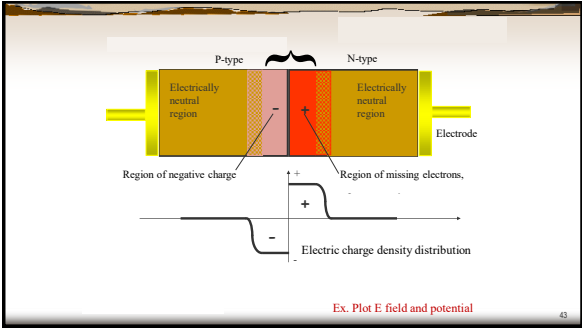
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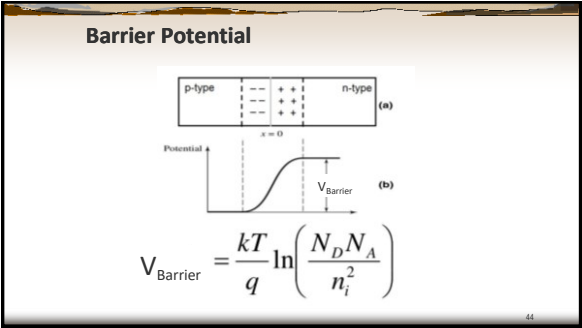
Energy Bands in p-n junction at equilibrium



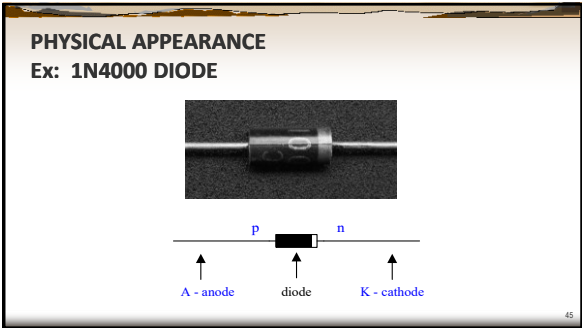
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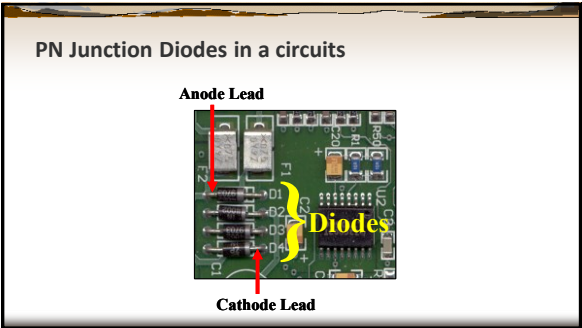
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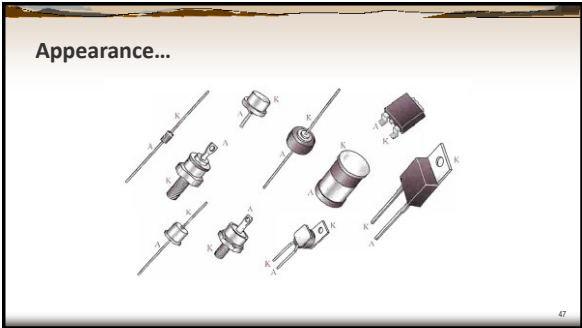
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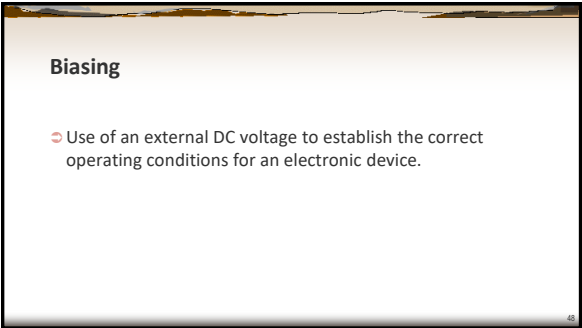
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### Forward Biased Diode

(a) Unbiased p-n junction: Shows a p-n junction with an internal electric field pointing from the n-region to the p-region. The p-region is labeled -V and the n-region is labeled +V.

(b) Forward biased diode: Shows a p-n junction connected to a battery with the positive terminal to the p-region and negative to the n-region. An external electric field points from the positive terminal to the negative terminal, opposing the internal field. The depletion layer is shown narrowing.

Majority Carriers Cross the Junction

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### Current and Voltage Measurement

A circuit diagram showing a DC voltage source connected in series with an ammeter (A) and a diode. The diode is connected in series with a voltmeter (V). The current through the diode is labeled  $i$ .

Ideal voltmeter measures diode's voltage, but no current flows through the voltmeter. But actual voltmeters allow very small current flow.

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### Forward Current

The diagram shows a p-n junction under forward bias with current  $I_f$  (majority) flowing from the p-region to the n-region. A graph of current  $I$  (mA) versus voltage  $V$  (volts) shows the characteristic curve of a diode, with a sharp increase in current after the cut-in voltage  $V_{cut-in}$ .

Forward current is due to majority carriers.

Depletion layer becomes narrow when positive voltage is applied to the diode. Then more electrons spill over from N to P part of diode.

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### Forward Characteristics

Two graphs showing the forward characteristics of a diode. The left graph plots forward current  $I_f$  (mA) against forward voltage  $V_f$  (volts), showing an exponential relationship. The right graph plots forward voltage  $V_f$  (volts) against forward current  $I_f$  (mA), showing a logarithmic relationship. A red circle highlights the region around the cut-in voltage  $V_{cut}$ .

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### Reverse Bias

A diagram of a p-n junction under reverse bias, with the positive terminal connected to the n-region and the negative terminal to the p-region. The depletion layer is shown widening, and the electric field is strengthened.

- Majority carriers move further away from the junction.
- Depletion Layer widens.

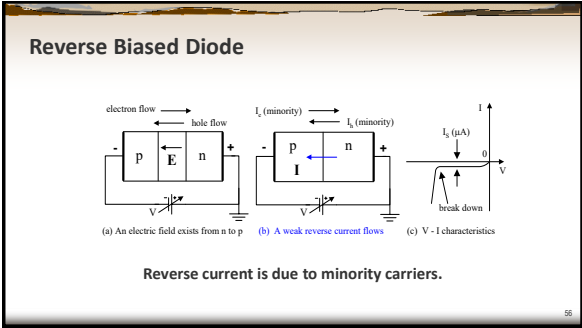
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### Reverse Current

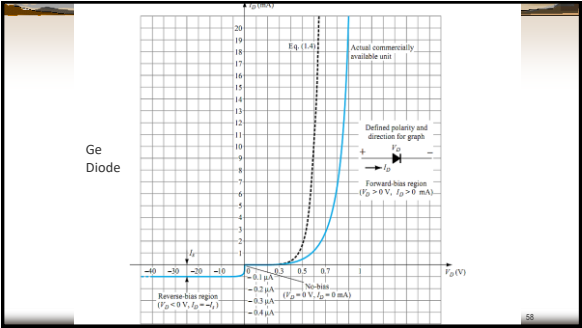
A diagram of a p-n junction under reverse bias, showing the movement of minority carriers across the junction. The electric field supports the movement of minority carriers.

- Minority carriers cross the junction.
- Small leakage current flows.
- Its called Reverse Saturation Current

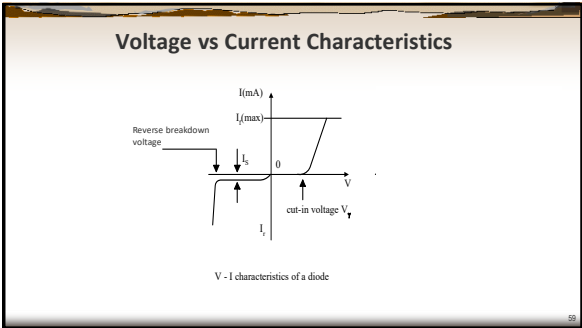
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