

Introduction to Electronics



An introduction to electronic components and a study of circuits containing such devices.

Week 4: Diodes Part 1





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Introduction to Electronics

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containing such devices.*





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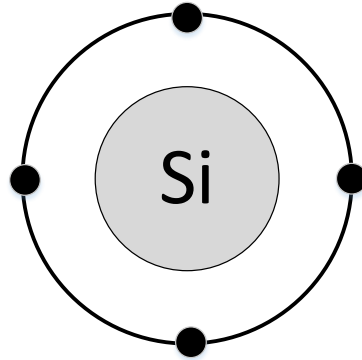
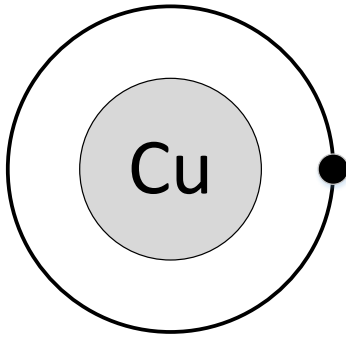
Introduction To PN Junctions

Introduce PN junctions and explain their physical behavior.

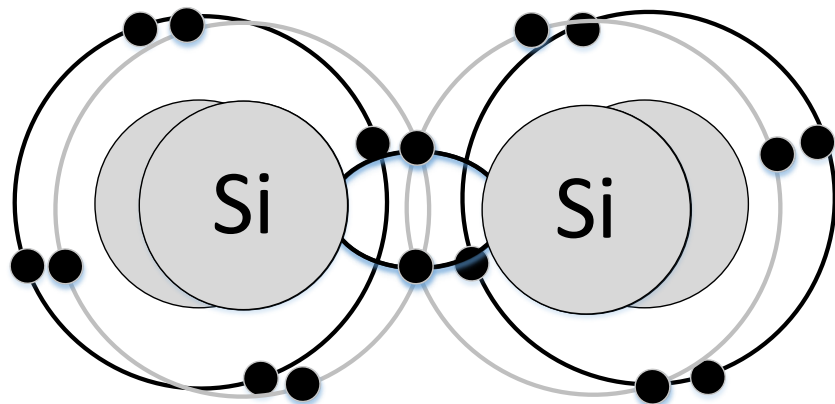


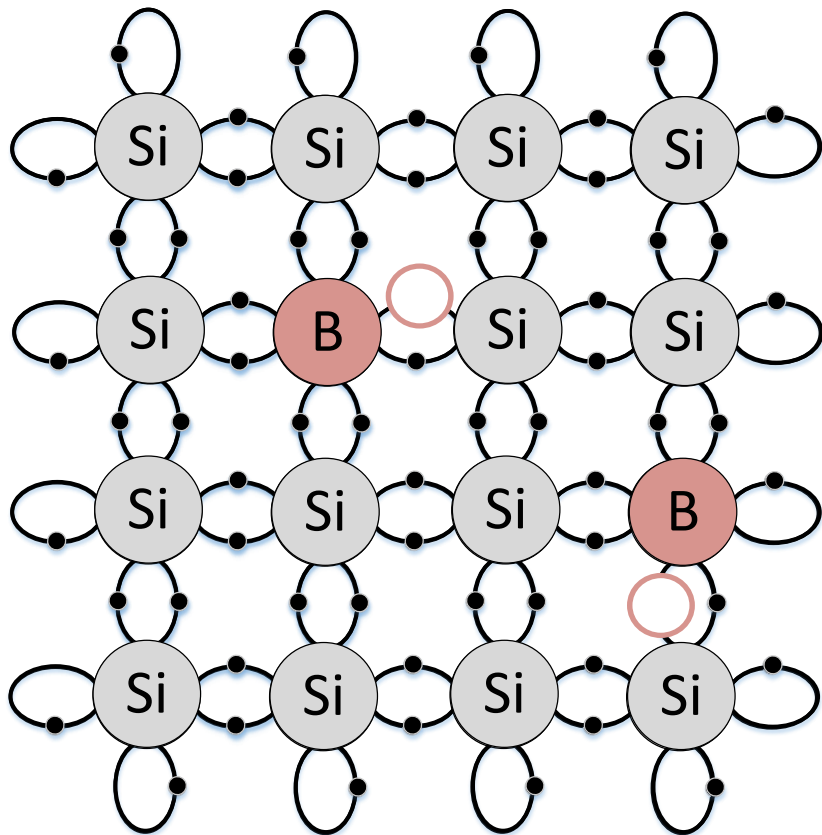
Lesson Objectives

- Demonstrate the physics of semiconductors
- Introduce PN Junctions



Semiconductor



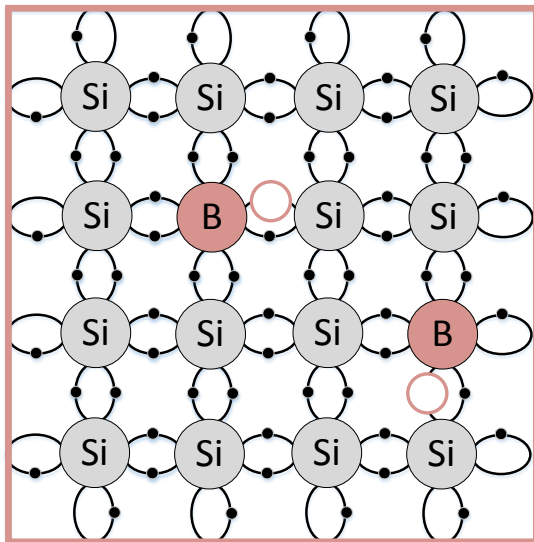


Doping - Add impurities such as Boron or Phosphorus

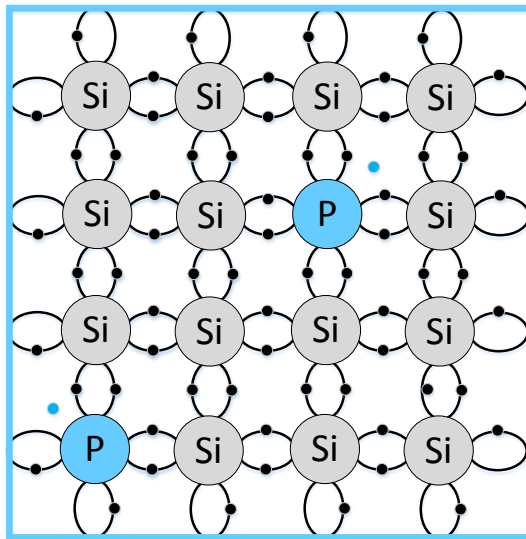
Number of electrons in outer shell:

- Boron has 3 electrons
- Phosphorus has 5 electrons

P-Type and N-Type Semiconductors

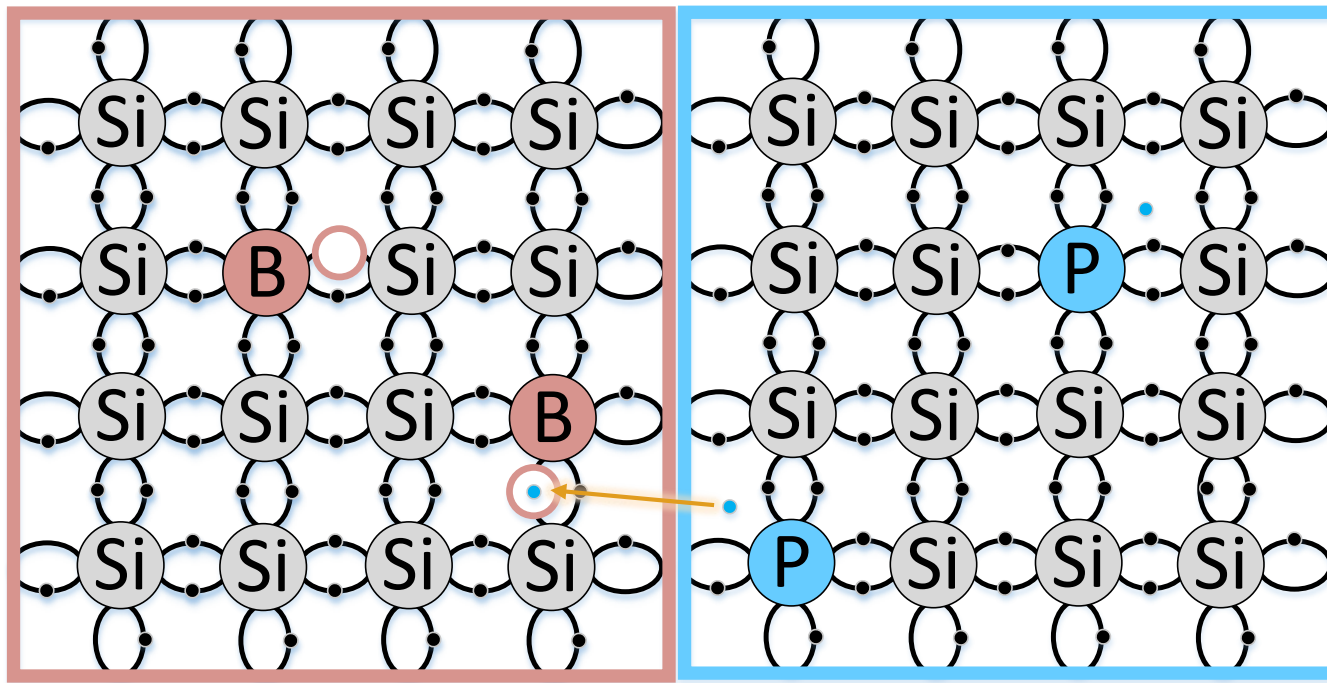


P-Type: extra holes



N-Type: extra free electrons

PN Junction

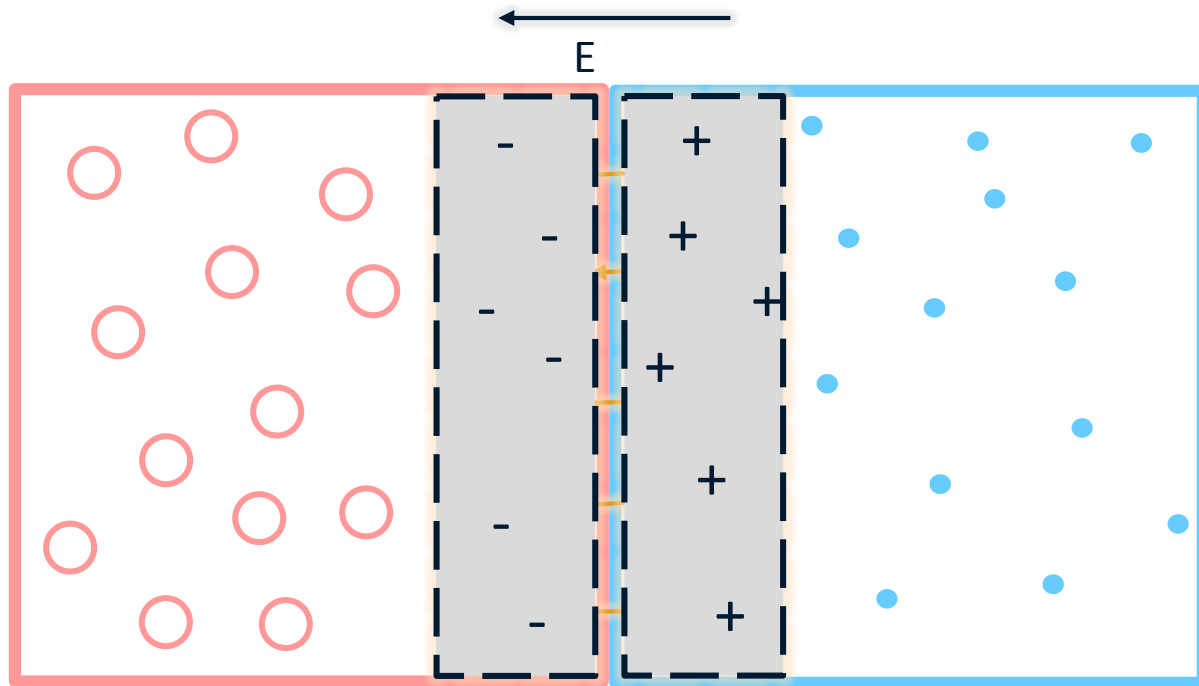


P-Type

N-Type

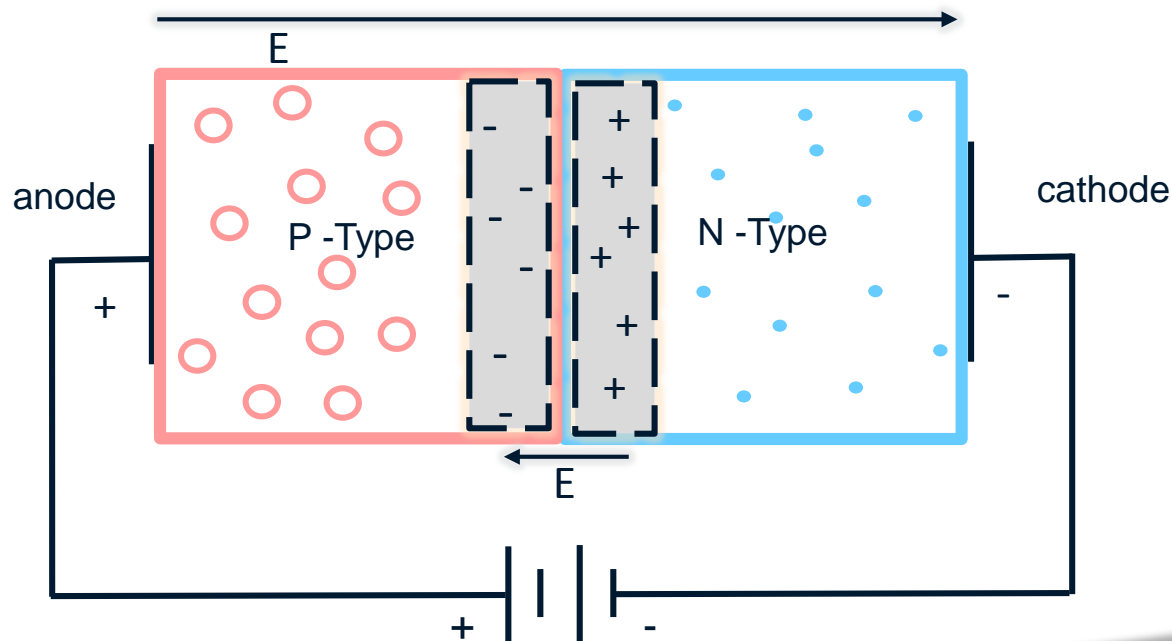
Energy – heat or light
makes electrons at
the junction diffuse
to fill nearest holes

PN Junction

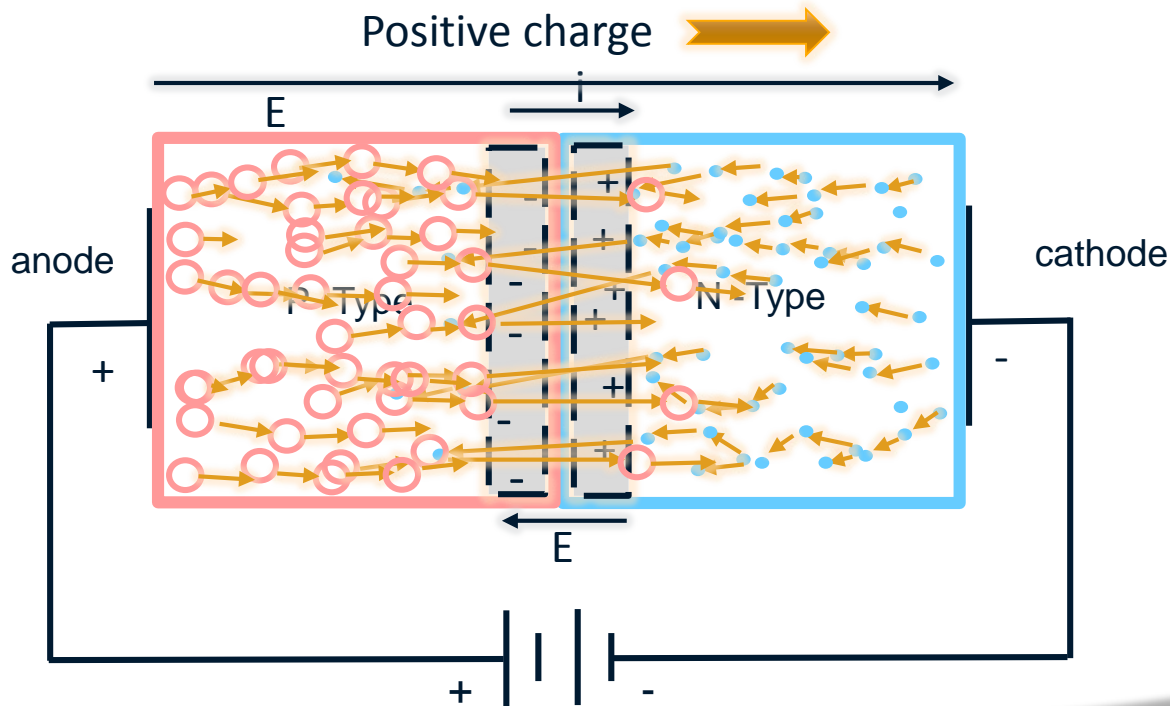


Depletion Region

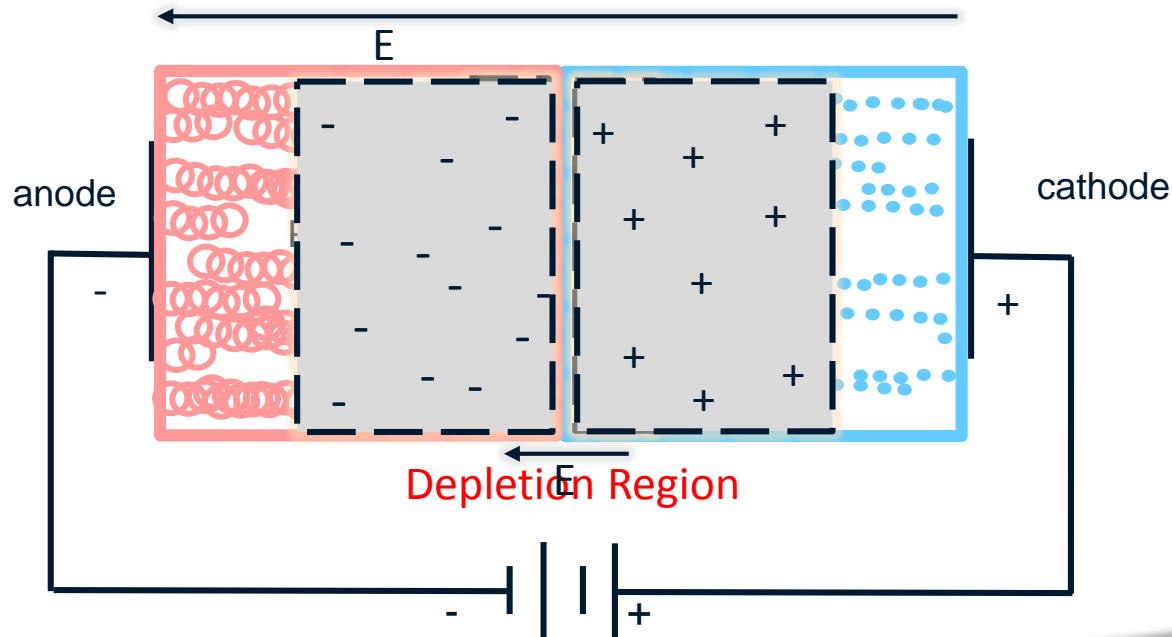
PN Junction: Conducting



PN Junction: Conducting

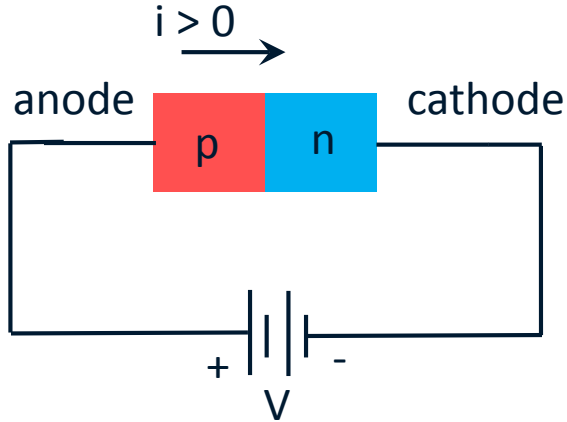


PN Junction: Not Conducting

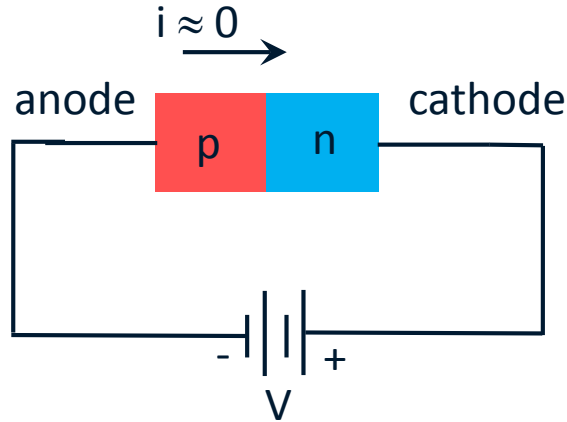


Summary of Behavior

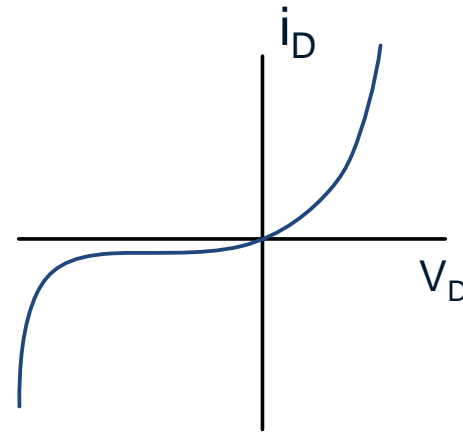
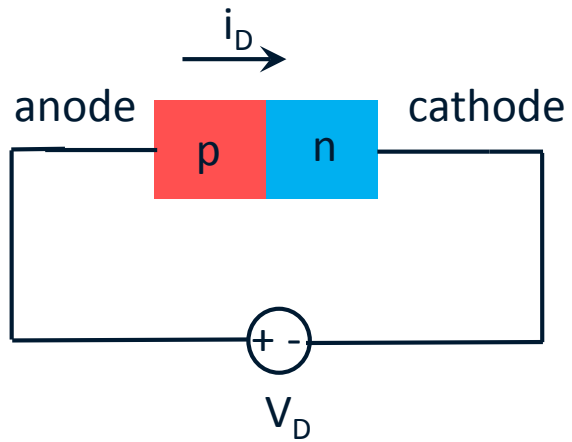
Conducting



Not Conducting

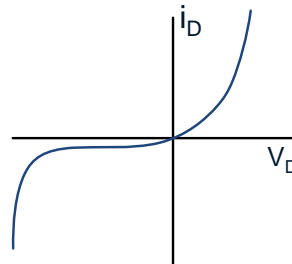
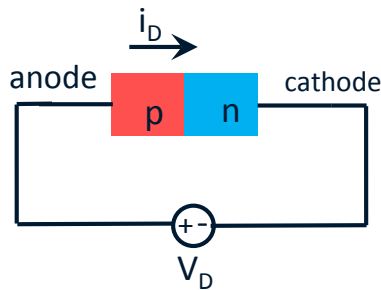


Diode



Summary

- Semiconductors become better conductors when
 - Doped
 - Exposed to heat or light
- PN Junctions (Diodes)



Remainder of Module 3: Diodes

- Circuit analysis with simple diode models
- Applications: rectifiers, AM detector, LEDs, voltage limiters, voltage regulators, AC to DC conversion



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Diode Behavior and Models

Introduce ideal and non-ideal diode I-V curves



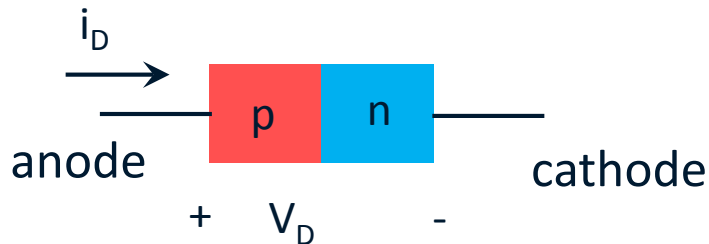
Previous Lesson

- The physics of PN junctions

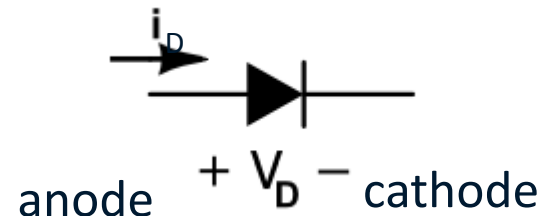
Lesson Objectives

- ⦿ Analyze diode behavior
- ⦿ Introduce diode applications
- ⦿ Describe different operating regions
- ⦿ Introduce simple diode models that approximate the actual device

Background



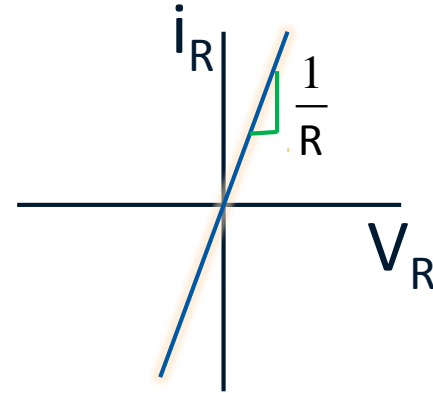
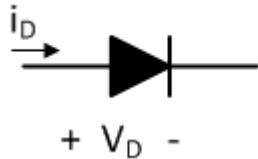
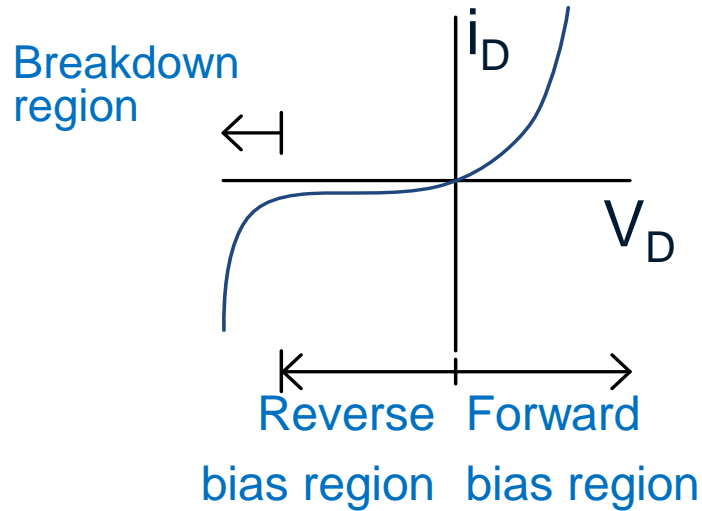
Circuit Symbol:



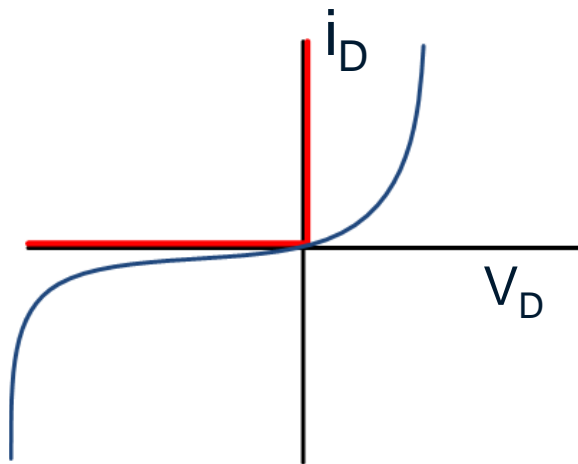
Uses:

- **Block current flow** in a specific direction
- **Rectifier** (AC to DC conversion)
- **Voltage regulator** and **limiter** (protection)
- **Light Emitting Diodes** (LEDs)
- **AM Detectors**
- **Electronic tuners**
- **Photodiodes**

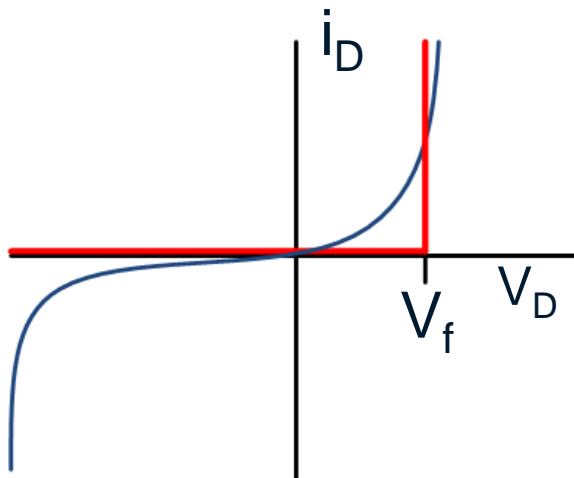
I-V Characteristics



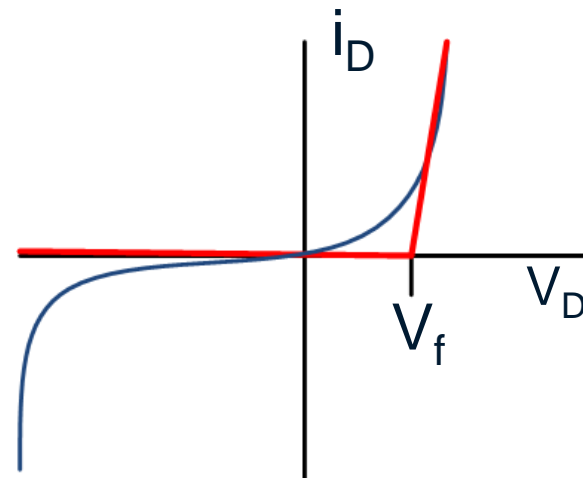
Simple Diode Models



Ideal Diode Model

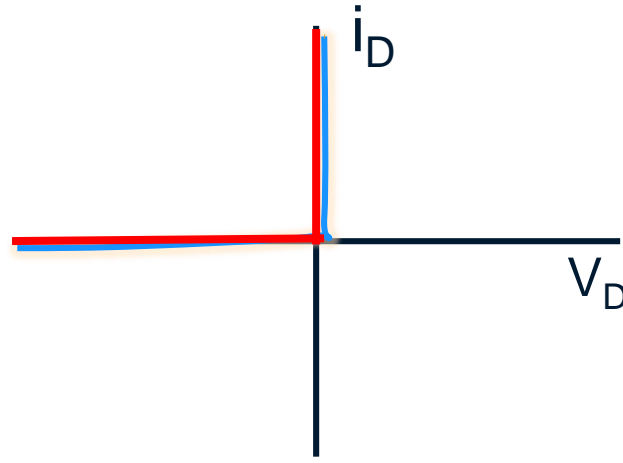
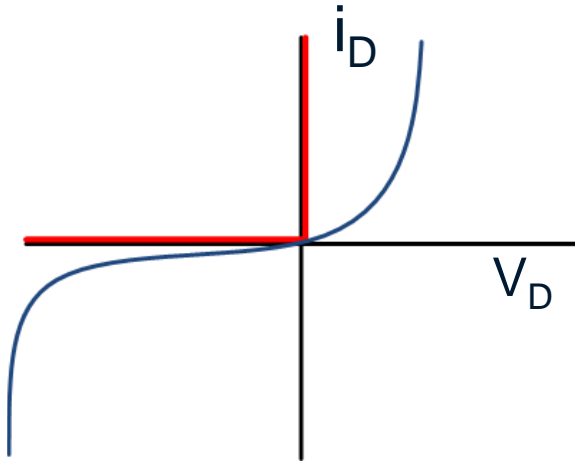


**Ideal Diode + Voltage
Source Model**



**Ideal Diode + Voltage
Source + Resistor Model**

Ideal Diode



Summary

- Diodes have three operating regions
 - Forward bias, $i_D > 0$
 - Reverse bias, $V_D < 0$
 - Breakdown
- Ideal diodes only allow current to flow in one direction
- Three models: ideal, ideal + voltage source, ideal + voltage source + resistor

Ideal Diode Model



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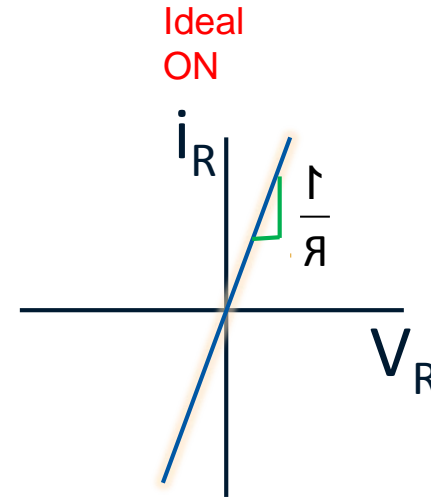
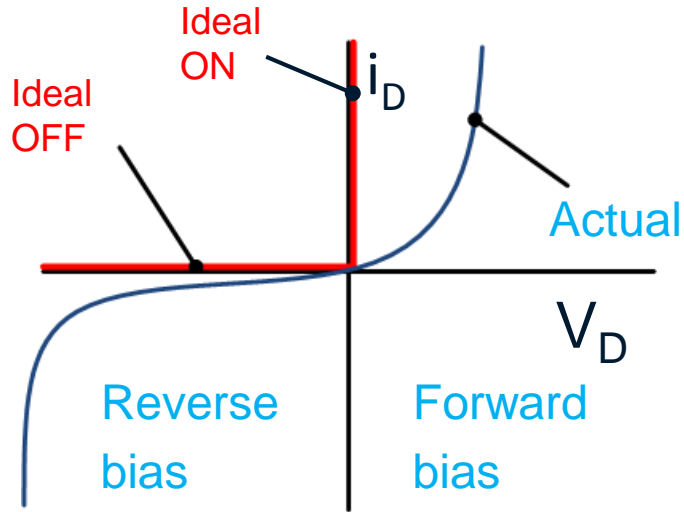
Introduce ideal diodes in circuits



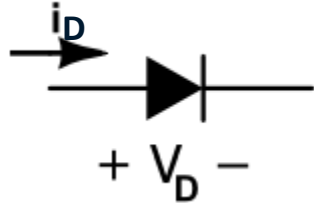
Lesson Objectives

- Introduce ideal diode operation
- Describe how to analyze DC diode circuits

Ideal Diode Model

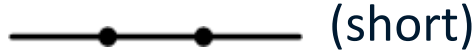
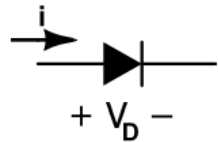


Ideal Diode Model



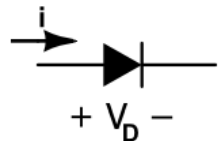
Two possible states: ON and OFF

ON (conducting): if $i_D > 0$

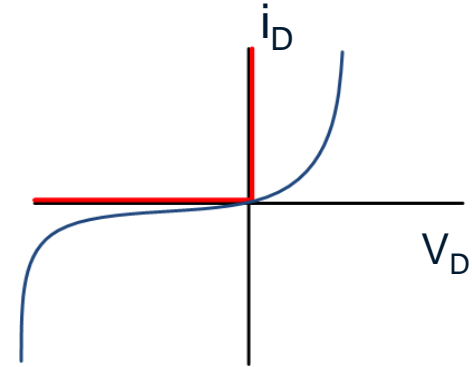


(short)

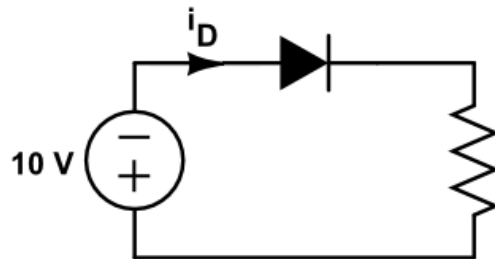
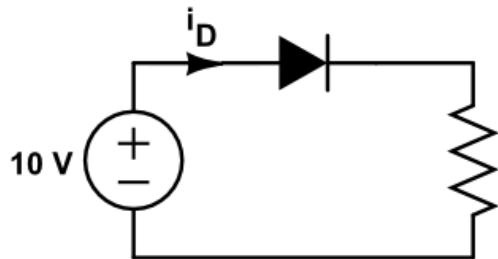
OFF (blocking): if $V_D < 0$, $i_D = 0$



(open)



Example



Summary

- Diodes act as a short or an open, depending on the bias



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Assumed States Method

Introduce ideal diode circuits with multiple diodes



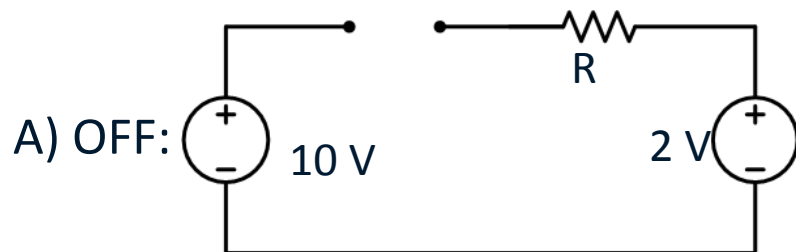
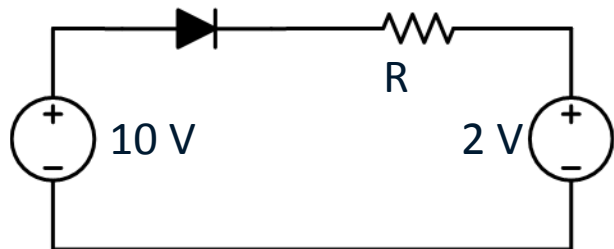
Lesson Objective

- Describe the procedure for handling multiple diodes in a single circuit

Assumed States Procedure

- 1) Identify all possible diode state combinations
 - 1 diode \Rightarrow 2 states
 - 2 diodes \Rightarrow 4 states
 - 3 diodes $\Rightarrow 2^3 = 8$ states
- 2) Analyze each state by replacing the diodes with the corresponding open or short.
- 3) Determine which state is consistent:
 - ON: $i_D > 0$
 - OFF: $V_D < 0$

Example



States	D1	Consistent?
A	OFF	
B	ON	

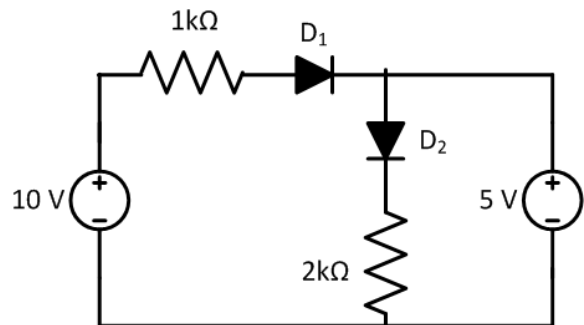
$$-10 + V_D + 2 = 0, V_D > 0$$

(not consistent)

$$-10 + i_D 1k + 2 = 0, i_D = 0.008A > 0$$

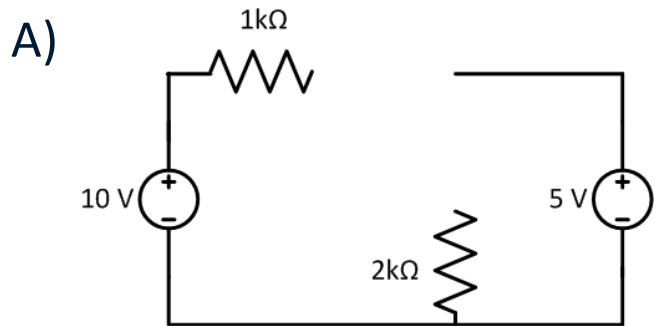
(consistent)

Two Diode Example



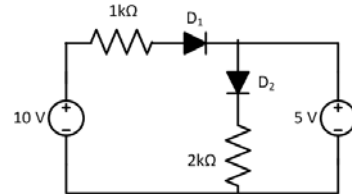
Find V_1

States	D1	D2	Consistent?
A	OFF	OFF	
B	OFF	ON	
C	ON	OFF	
D	ON	ON	

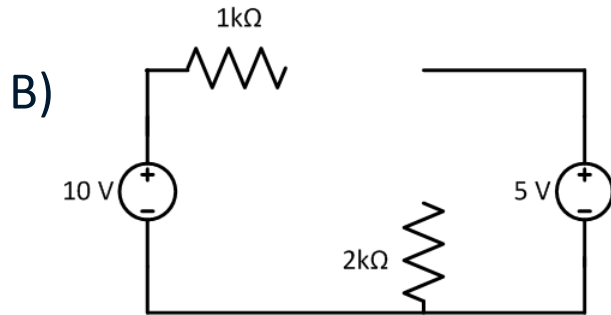


KVL: $-5 + V_{D2} = 0 \Rightarrow V_{D1} = 5 > 0$
(Not consistent)

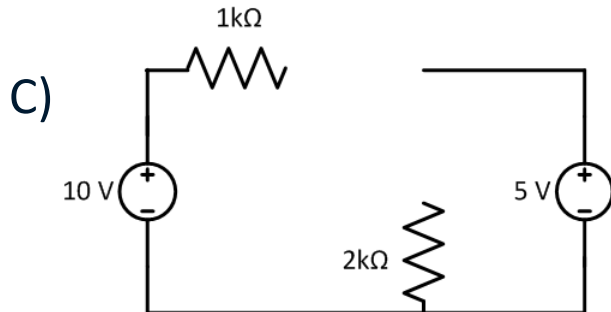
Example continued



States	D1	D2	Consistent?
A	OFF	OFF	No
B	OFF	ON	
C	ON	OFF	
D	ON	ON	

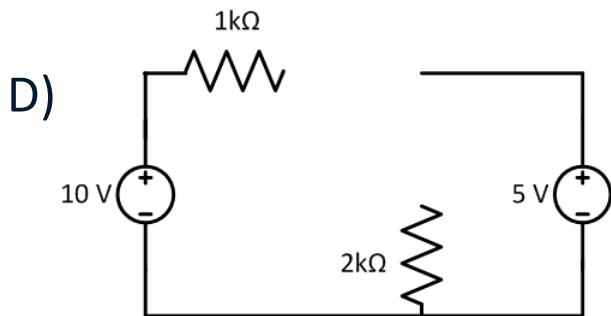


KVL: $-10 + V_{D1} + 5 = 0$, $V_{D1} = 5V > 0$
(Not consistent)



$V_{D2} = 5V > 0$
(Not consistent)

Example continued

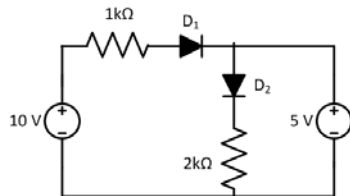


$$\text{KVL: } -10 + 1000i_{D1} + 5 = 0$$

$$i_{D1} = 0.005\text{A} > 0$$

$$i_{D2} = 5/2000 > 0$$

(Consistent)



States	D1	D2	Consistent?
A	OFF	OFF	No
B	OFF	ON	No
C	ON	OFF	No
D	ON	ON	

Operating state:

D_1 and D_2 are ON

$$V_1 = 1000(0.005) = 5\text{V}$$

Summary

- Diodes act as a short or an open, depending on the bias
- When solving a circuit, assume each possible state, and check to see if the behavior is consistent with that state



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Ideal Diode + Voltage Source Model

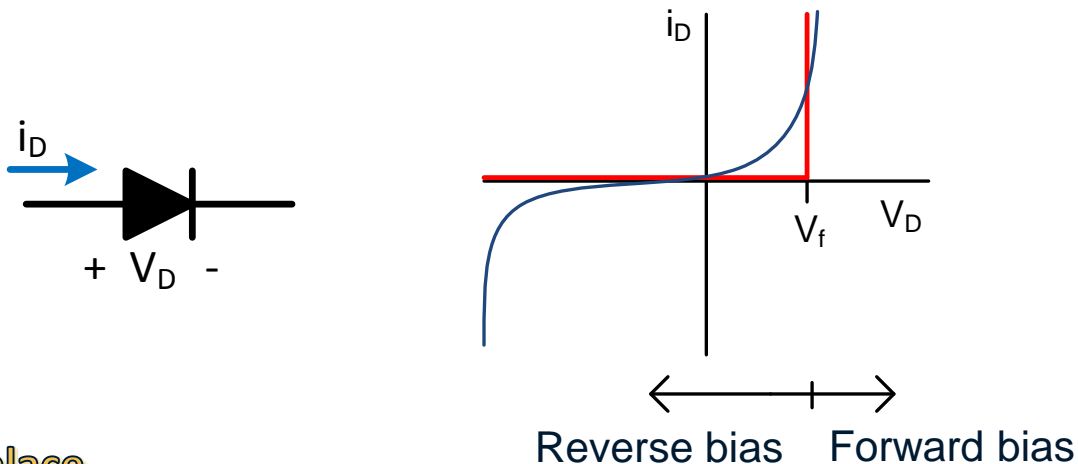
Introduce another diode model for circuit analysis



Lesson Objective

- Examine the ideal diode + voltage source model

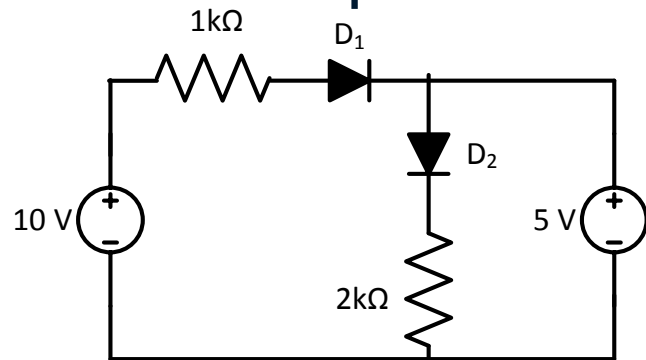
Ideal Diode with a Voltage Source



Replace

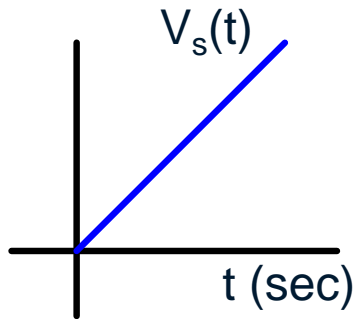
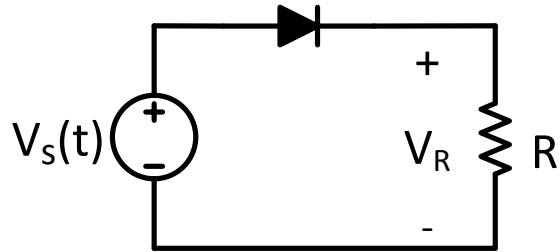


Example



States	D1	D2	Consistent?
A	OFF	OFF	
B	OFF	ON	
C	ON	OFF	
D	ON	ON	

Example



Summary

- Ideal diode + voltage source model has threshold voltage that must be surpassed before the diode is turned on.
 - 0.7 V Silicon
 - 0.3-0.4 V Germanium
 - 1- 4 V LED
- Replace diode with ideal diode + voltage source and analyze using ideal diode methods.