Electronic Devices and Circuits

EME306

(Summer 2021-2022)

Lecture 1&2

Introduction

INSTRUCTOR

Dr / Ayman Soliman

➢ Contents

1) Course Contents.

2) Grading System & distribution.

3) Course Information.

4) Course Policy.

5) Introduction.

1) Course Contents.

- Semiconductor physics,
- Structure of diodes, Diode circuits and rectifiers,
- Structure of BJT, Biasing and operation modes of transistors,
- DC and small signal analysis of transistor circuits,
- Amplifiers circuits using BJT, Power amplifiers,
- Field effect transistors, Biasing of FET,
- Small signal model of FET.
- Amplifier circuits using FET, Design of amplifier circuits,

1) Course Contents.

- Frequency response of amplifier circuits,
- Active filters,
- Feedback in electronic circuits,
- Different feedback configurations in electronic circuits,
- Oscillators circuits.

2) Grading System & distribution.

Total score (100%)

- Midterm 1
  8^{th} week
  (30%)
- Midterm 2
  12^{nd} week
  (20%)
- Lec. & Sec & Lab & Project
  (10%)
- Final exam
  (40%)

3) Course Information.

Lectures: Saturday, Tuesday, (9:00 - 10:35 AM)

Office Hours: Saturday, Tuesday.

Prerequisite: EME208 Electric Circuits II

References:

- Microelectronic Circuits by Adel S. Sedra and Kenneth C. Smith , Oxford University press.
- My Lectures.
- Prof. Ashraf Shawky lectures

Instructor:

Dr. Ayman Soliman

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TAs:

Eng.

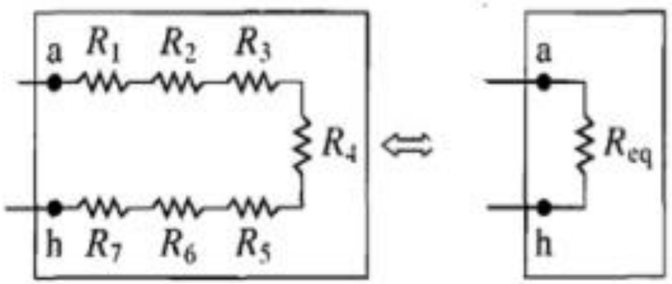
4) Course Policy.

- Any forms of **cheating or plagiarism** will result in a **Zero grade** for the required task, report or exam (No discussion nor excuses).

- Students are expected to **respect** Instructors, TAs, and their colleagues.
- Be **on time** and cell phones should be silent or off during the lecture.
- Your grades is based on **merit only** nothing else.

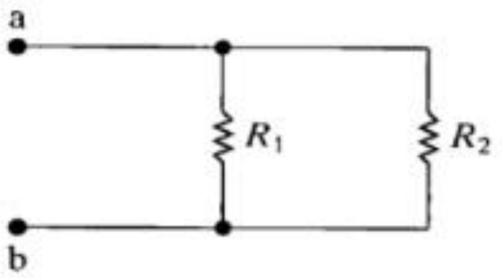
The Series Resistors

$$R_{eq} = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7$$

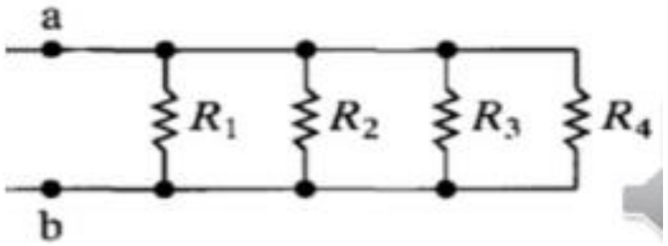


The Parallel Resistors

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}.$$



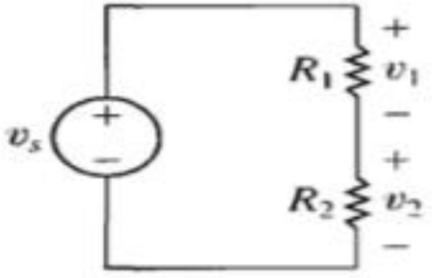
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}.$$



The voltage divider

$$v_1 = iR_1 = v_s \frac{R_1}{R_1 + R_2},$$

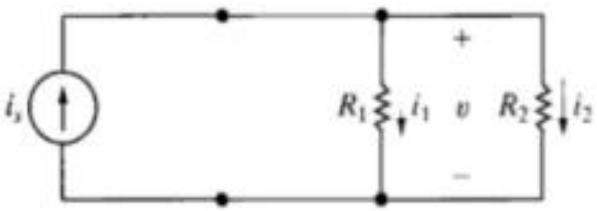
$$v_2 = iR_2 = v_s \frac{R_2}{R_1 + R_2}.$$



The current divider

$$i_1 = \frac{R_2}{R_1 + R_2} i_s,$$

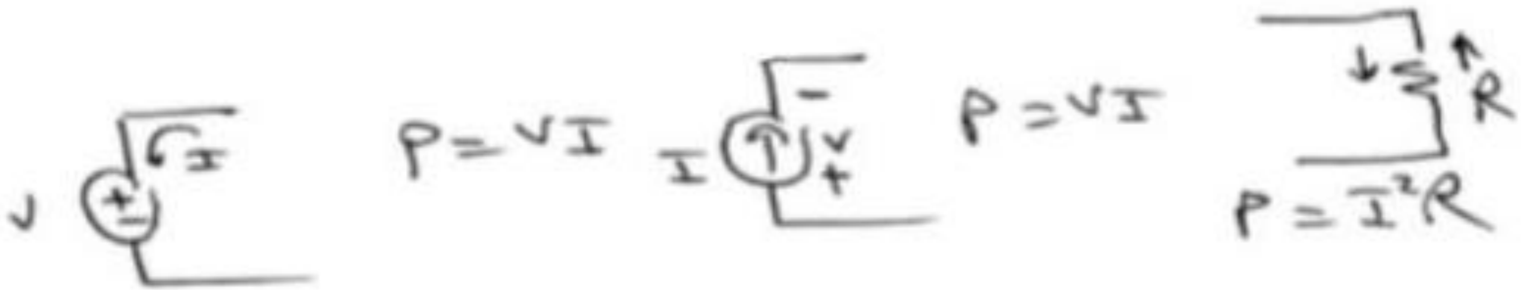
$$i_2 = \frac{R_1}{R_1 + R_2} i_s.$$



Voltage source to current source and vice versa

The Delivered power

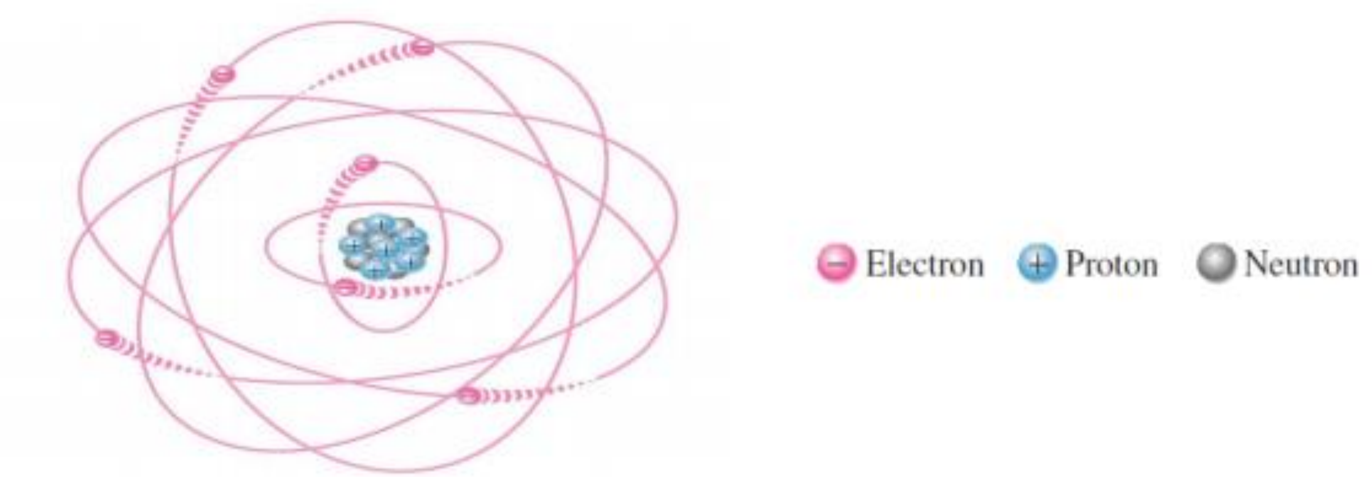
The Consumed or dissipated power



The atomic structure

1- The Bohr Model

- **An atom is the smallest particle of an element that retains the characteristics of that element.**
- **Atoms consists of a central nucleus surrounded by orbiting *electrons***
- **The nucleus consists of *positively charged* particles called *protons* and *uncharged particles* called *neutrons.***



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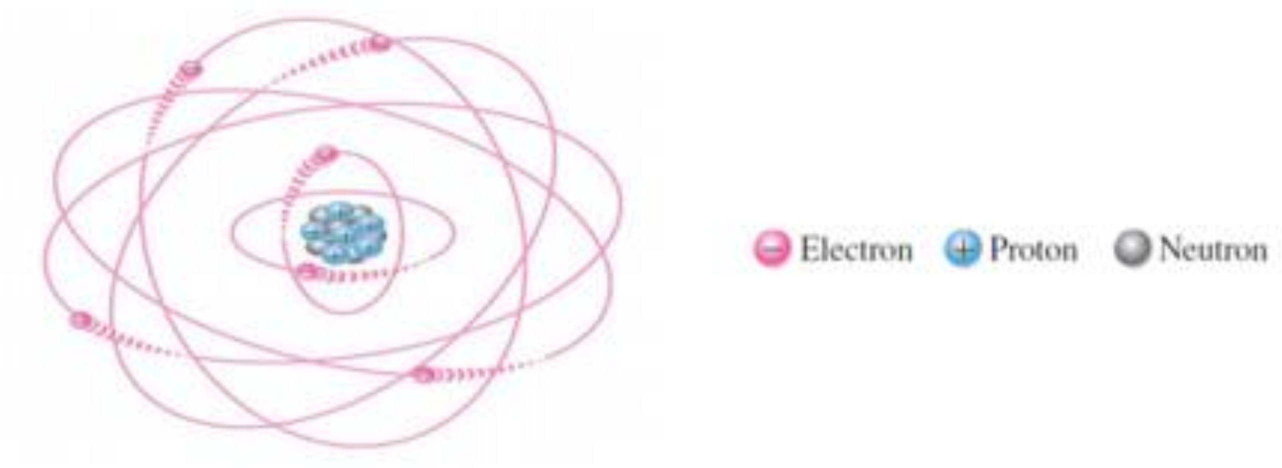


Materials used in electronics

1- Superconductor

2- Conductor

3- Semiconductor

4- Dielectric

5- Insulator

1- Superconductor

phenomenon was discovered in 1911 by Dutch physicist Heike Kamerlingh Onnes.

Superconductor material is constructed from alloys of materials and has zero resistance at certain temperature

Superconductor Applications

1- Superconducting magnets **are some of the most powerful** electromagnets **known.**

2-in MRI Magnetic resonance **imaging (MRI) / Nnuclear** magnetic resonance **(NMR) machines.**

3-in large wind turbines to overcome the restrictions imposed by high electrical current

4- in digital circuits **based on** rapid single flux quantu**m technology .**

5- in RF and microwave filters **for** mobile phone **base stations.**

2- Conductor

- A conductor is a material that easily conducts electrical current.

- Most metals are good conductors

- The best conductors are single-element materials, such as copper (Cu), silver (Ag), gold (Au), and aluminum (Al), which are characterized by atoms with only one valence electron very loosely bound to the atom.

3- Semiconductor

- A semiconductor is a material that is between conductors and insulators in its ability to conduct electrical current.

- A semiconductor in its pure (intrinsic) state is neither a good conductor nor a good insulator.

- Silicon is the most commonly used semiconductor.

Semiconductor can be classified as

- **Single-element semiconductors** are **antimony** (Sb), **arsenic** (As), **boron** (B), **polonium** (Po), **tellurium** (Te), **silicon** (Si), and **germanium** (Ge)., Where are characterized by atoms with **four valence electrons**.

- **Compound semiconductors** such as **gallium arsenide**, **indium phosphide**, **gallium nitride**, silicon carbide, and silicon germanium are also commonly used.

4- Dielectric

- **Dielectric** is an electrical insulator that can be polarized by an applied electric field.

Polar molecules in dielectric without electric field

B. Polar molecules in the dielectric with the application of electric field

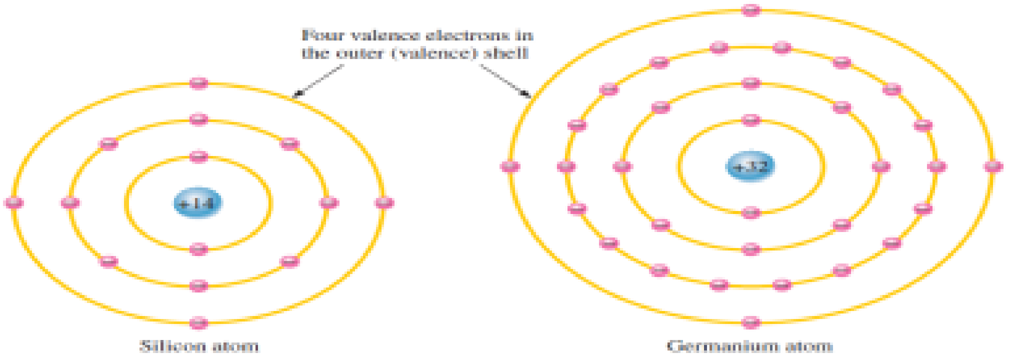
Application of dielectrics

- **Dry air is an excellent dielectric, and is used in variable capacitors and some types of transmission lines.**
- **Distilled water is a fair dielectric.**
- **A vacuum is an exceptionally efficient dielectric.**

5- Insulators

- An insulator is a material that does not conduct electrical current under normal conditions.
- Most good insulators are compounds rather than single-element materials and have very high resistivities.
- Valence electrons are tightly bound to the atoms; therefore, there are very few free electrons in an insulator.
- Examples of insulators are rubber, plastics, glass, mica, and quartz.

Comparison of a Silicon and Germanium



For silicon Si (N=14)

$1s^2, 2s^2, 2p^6, 3s^2, 3p^2$

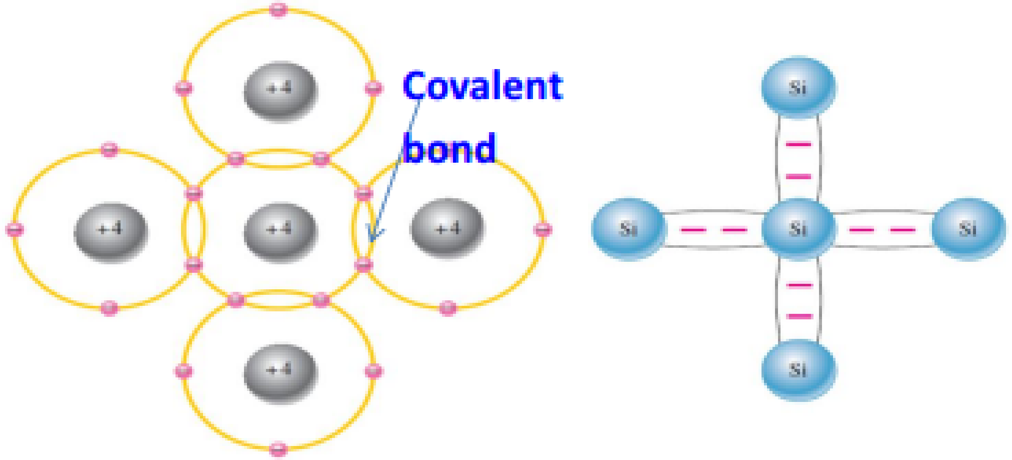
For Germanium Ge (N=32)

$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^2, 4p^2$

- V(barrier) for silicon is = **0.5 - 0.7 V**
- V(Barrier) for Germanium is= **0.2 - 0.3 V**
- This property makes **germanium more unstable** at high temperatures and results in excessive reverse current.
- This is why silicon is a **more widely used** semiconductive material.

Covalent Bonds

- A silicon (Si) atom with its four valence electrons shares an electron with each of its four neighbors.



(a) The center silicon atom shares an electron with each of the four surrounding silicon atoms, creating a

(b) Bonding diagram. The red negative signs represent the shared valence electrons.

- This effectively creates eight shared valence electrons for each atom and produces a state of chemical stability.
- Each valence electron is attracted equally by the two adjacent atoms which share it.
- Covalent bonding in an **intrinsic silicon** crystal
- An **intrinsic crystal** is one that has no impurities.
- Covalent bonding for germanium is similar because it also has four valence electrons.

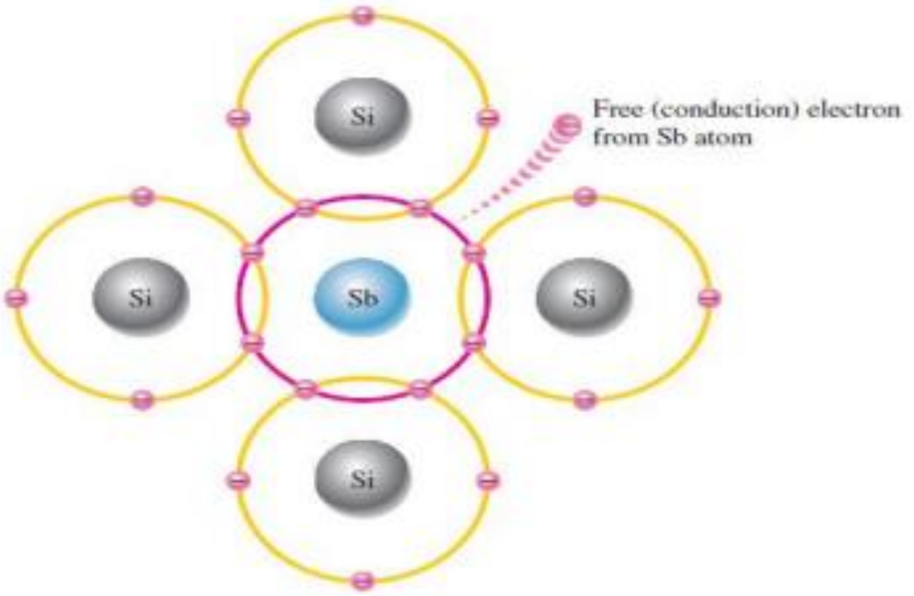
N-Type Semiconductor

- To increase the number of conduction-band electrons in intrinsic silicon, pentavalent impurity atoms are added.

- These are atoms with five valence electrons such as
  - **Arsenic** (As), N = 33, (2-8-18-5)
  - **Phosphorus** (P), N = 15, (2-8-5)
  - **Bismuth** (Bi), N = 83, (2-8-18-32-18-5)
  - **Antimony** (Sb), N = 51, (2-8-18-18-5)

- Each pentavalent atom forms covalent bonds with four adjacent silicon atoms.

- Four of the pentavalent atom's valence electrons are used to form the covalent bonds with silicon atoms, leaving one extra electron

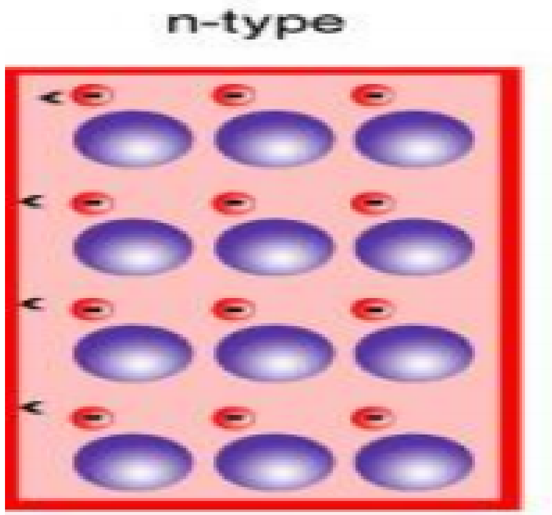


- This extra electron becomes a conduction electron because it is not involved in bonding.
- Because the ***pentavalent atom*** gives up an electron, it is often called a ***donor atom.***
- Process of added impurities to silicon called **doping**

Majority and Minority Carriers

- The most of the current carriers are electrons, when silicon (or germanium) doped with pentavalent atoms.

- The electrons are called the majority carriers in N-type material while Holes in an *n*-type material are called minority carriers.



Due to Negative free charge (electrons), material called N-type

P-Type Semiconductor

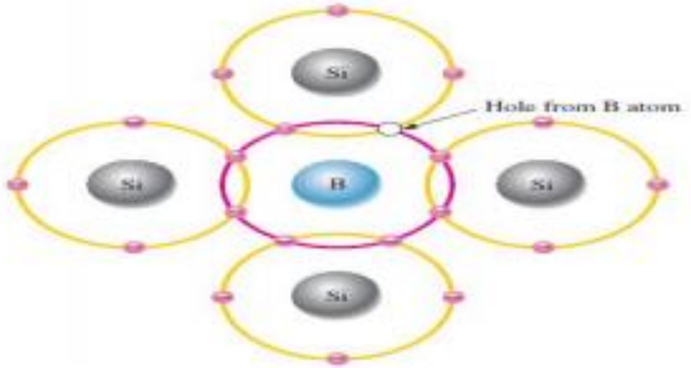
- To increase the number of holes in intrinsic silicon, **trivalent** impurity atoms are added.
- These are atoms with three valence electrons such as

  Boron (B), (N=5), (2-3)

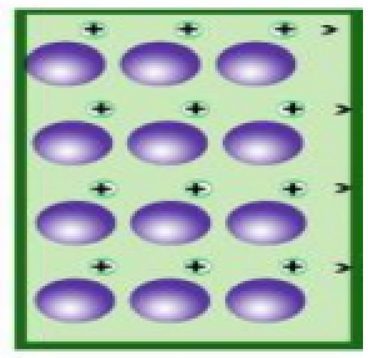
  Indium (In), (N=49), (2-8-18-18-3)

  Gallium (Ga), (N=31), (2-8-18-3)

- All three of the trivalent atom's valence electrons are used in the covalent bonds; and, since four electrons are required, **a hole** results when each trivalent atom is added.



- Because the **trivalent atom** can take an electron, it is often referred to as an **acceptor** *atom*.



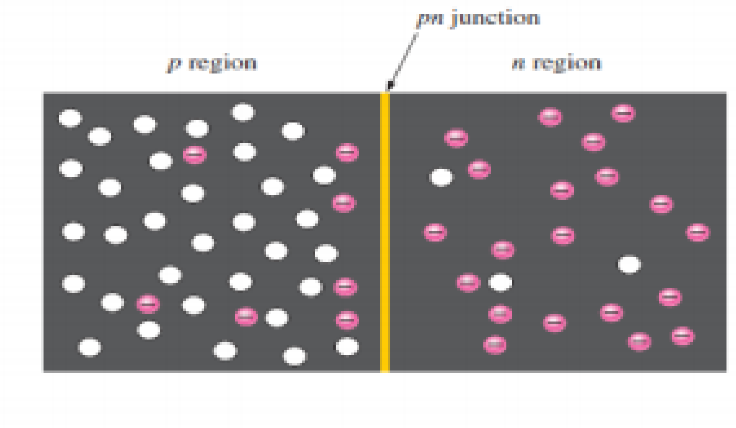
Due to Positive free charge (holes), material called P-type

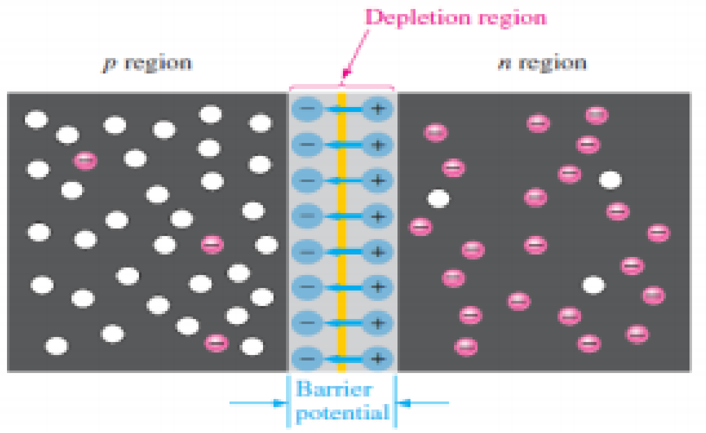
Majority and Minority Carriers

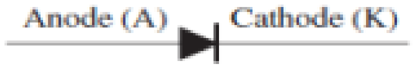
- The holes are the **majority carriers** in *p*-type material.
- The majority of current carriers in *p*-type material are holes.
- Conduction-band **electrons** in *p*-type material are the minority carriers

THE *PN* JUNCTION

If a piece of *n*-type and the other is *p*-type, a **PN junction** forms at the boundary between the two regions and a diode (**di**-electr**ode**) is created.

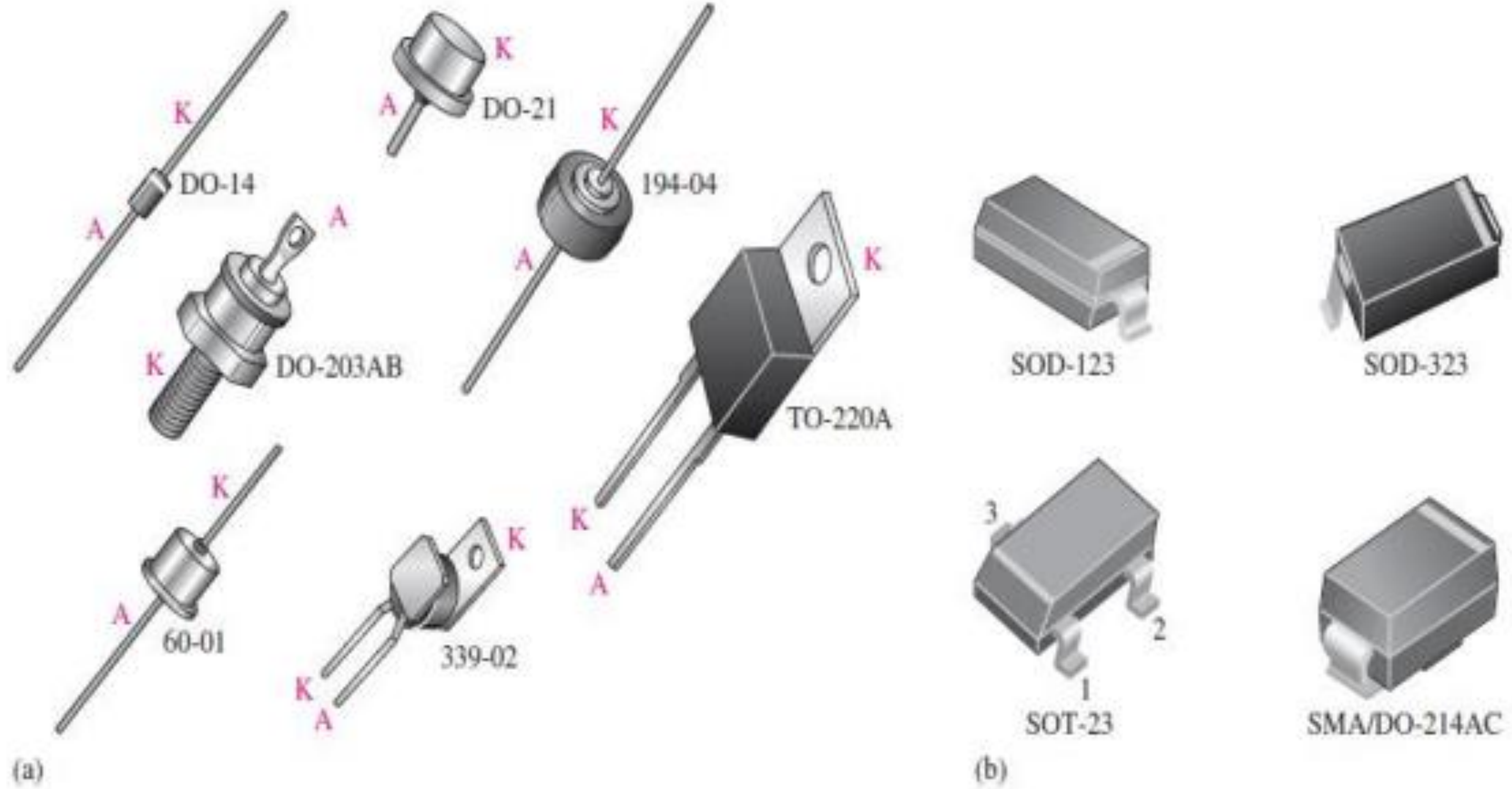






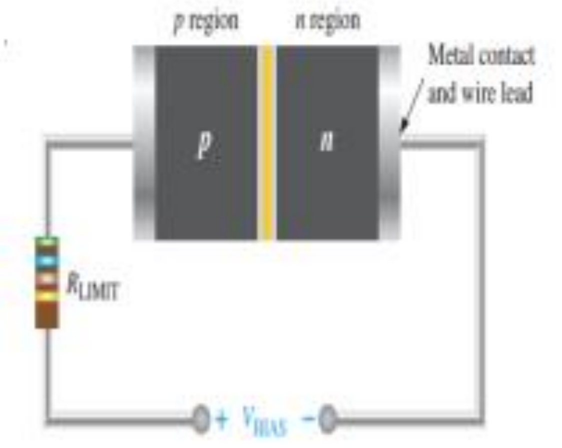
(b) Symbol


Anode (A)
Cathode (K)

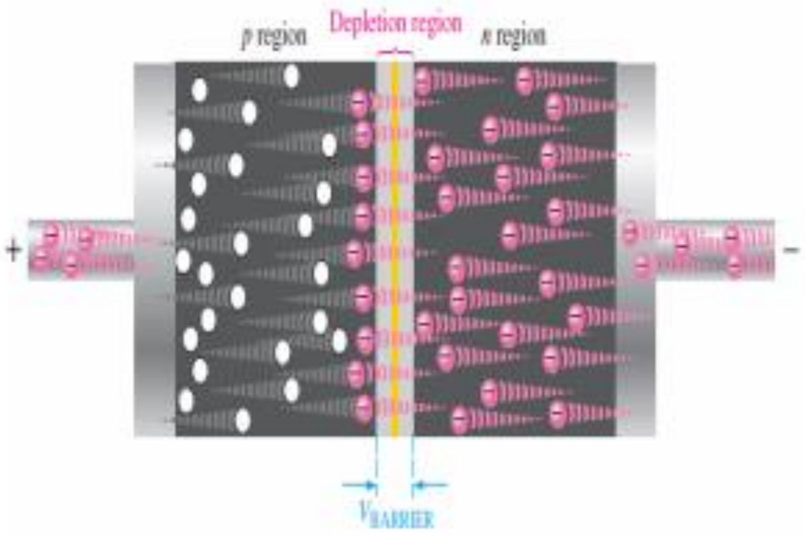

K
A
DO-14
K
A
DO-21
K
A
194-04
A
K
DO-203AB
K
A
TO-220A
K
A
60-01
K
K
A
339-02
SOD-123
SOD-323
3
2
1
SOT-23
SMA/DO-214AC
(a)
(b)

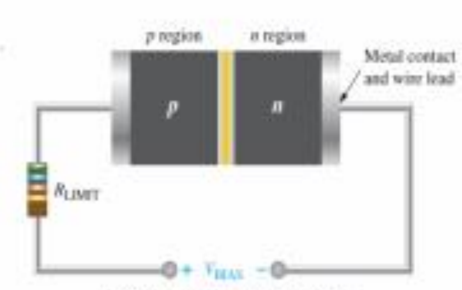
1- Forward Bias

When battery connected as shown, and the bias voltage, V_{BIAS}, must be greater than the barrier potential to make current flows and diode be on

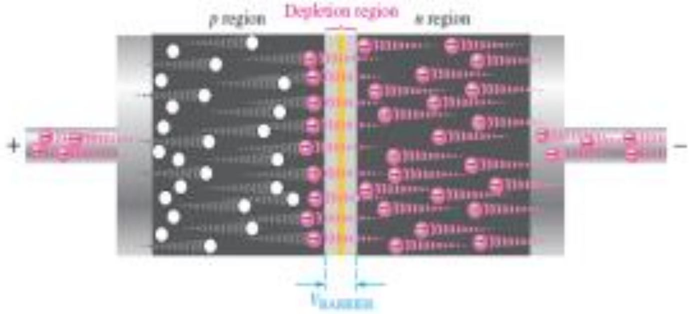


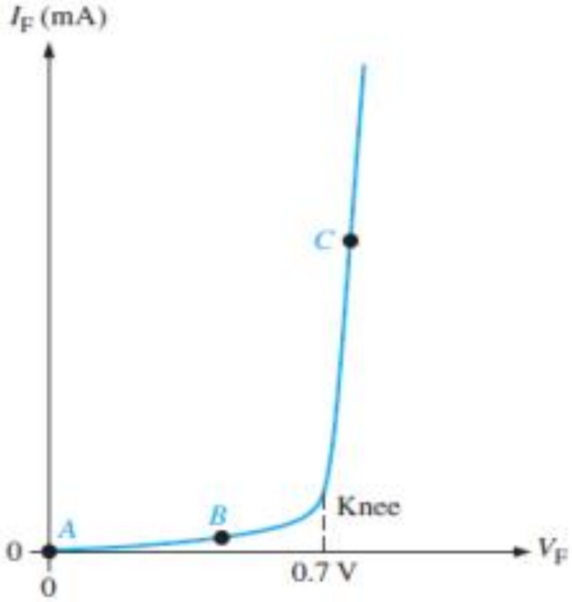
A diode connected for forward bias.



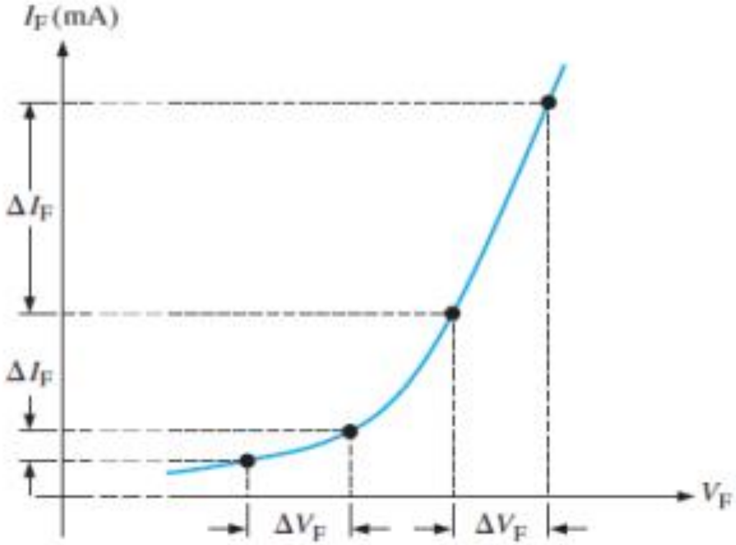


A diode connected for forward bias.





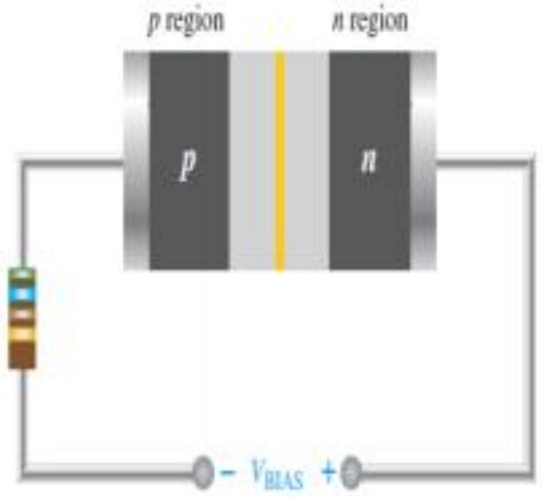
(a) *V-I* characteristic curve for forward bias.

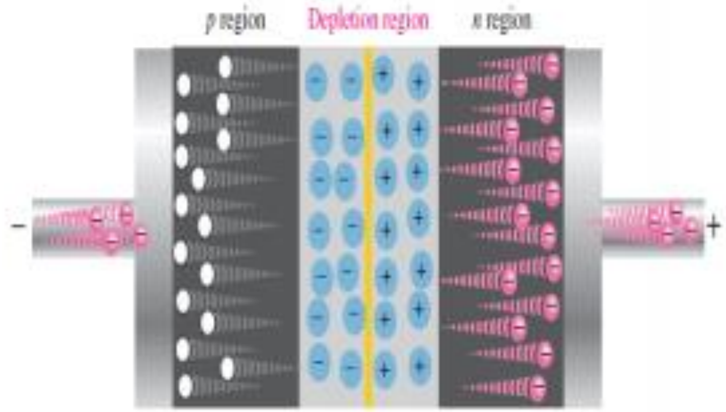


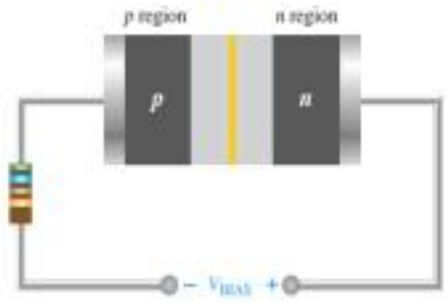
(b) Expanded view of a portion of the curve in part (a). The dynamic resistance r'_d decreases as you move up the curve, as indicated by the decrease in the value of $\Delta V_F / \Delta I_F$.

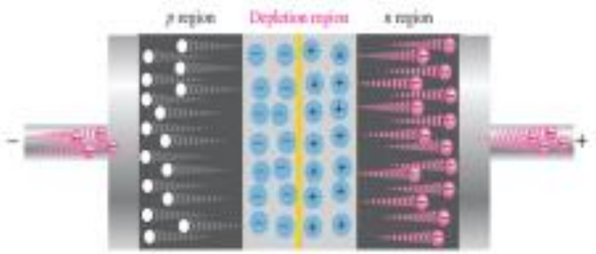
2- Reverse bias

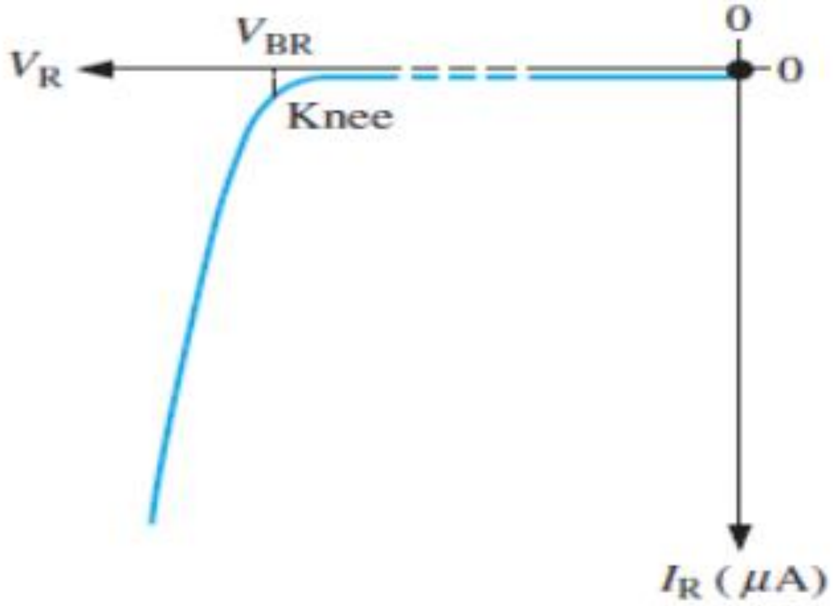
When battery is connected as shown, the depletion region is shown much wider than in forward bias or equilibrium., no current passes except very small current due to minority carriers





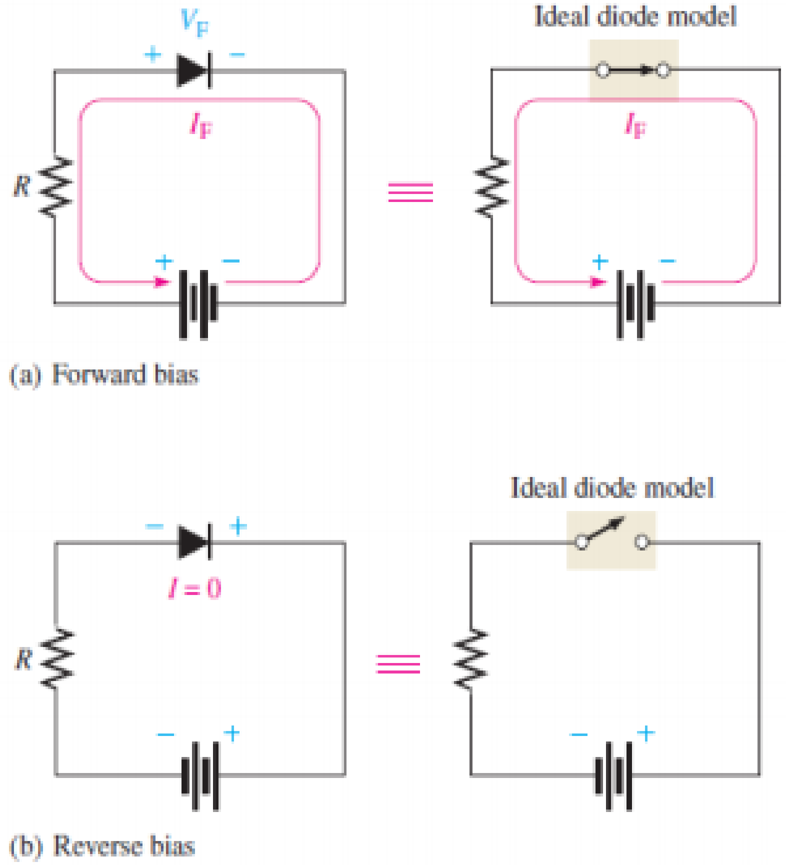

p region
n region
p
n
– V_BIAS +

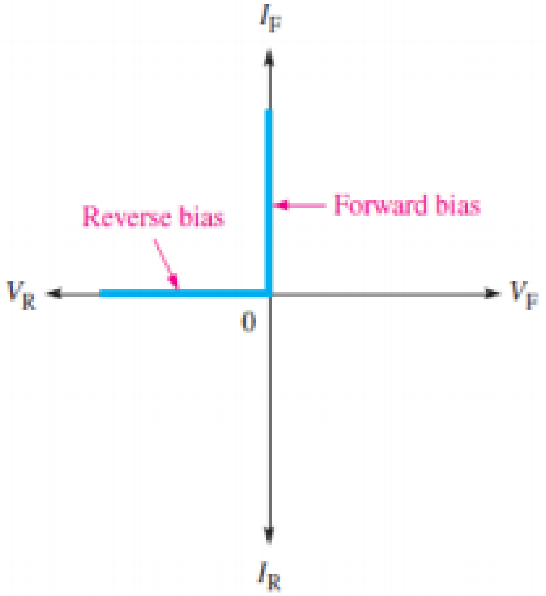

p region
Depletion region
n region
–
+


V_BR
V_R
0
0
Knee
I_R (μA)

DIODE MODELS

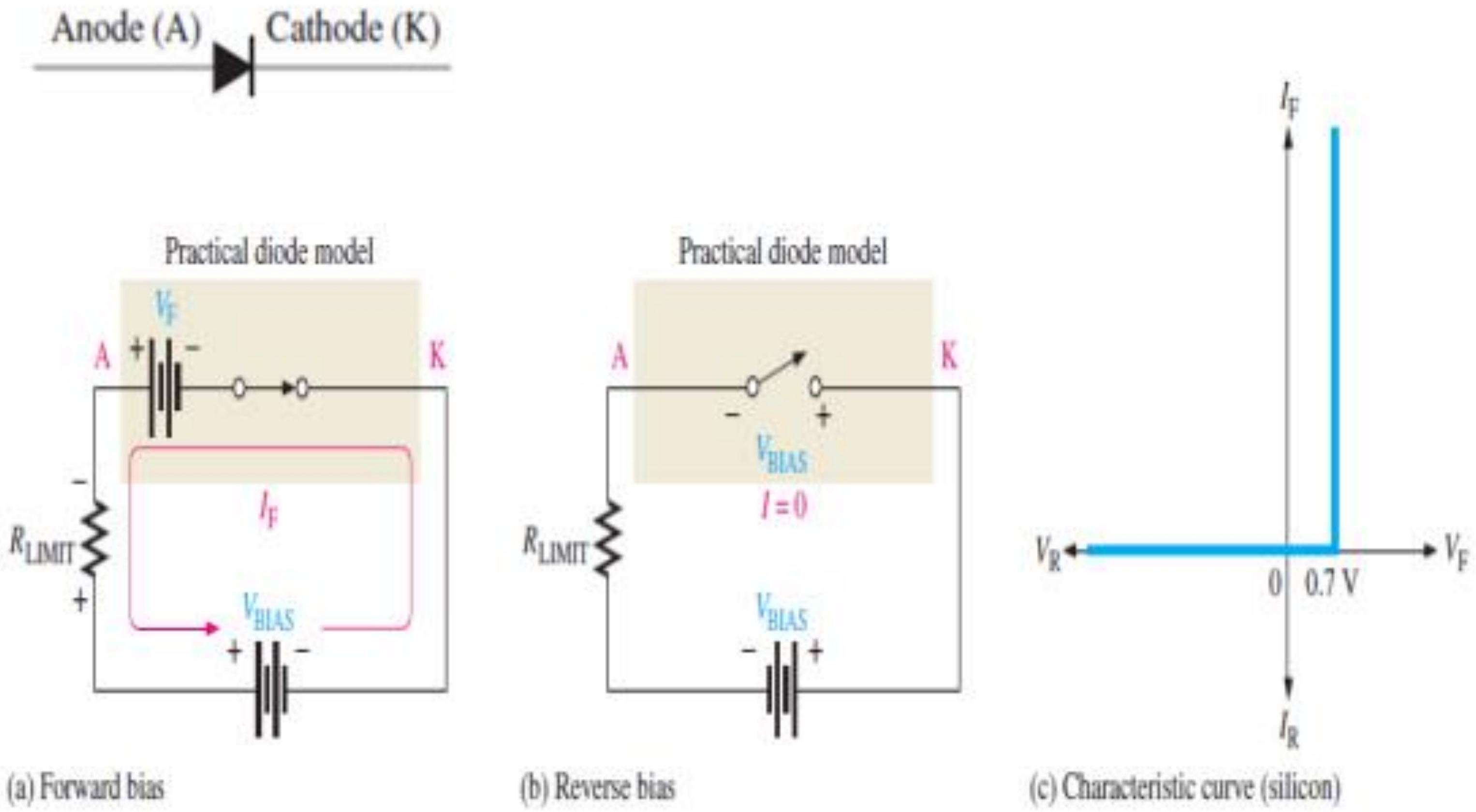
1- The Ideal Diode Model



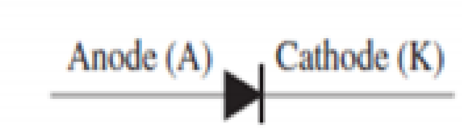


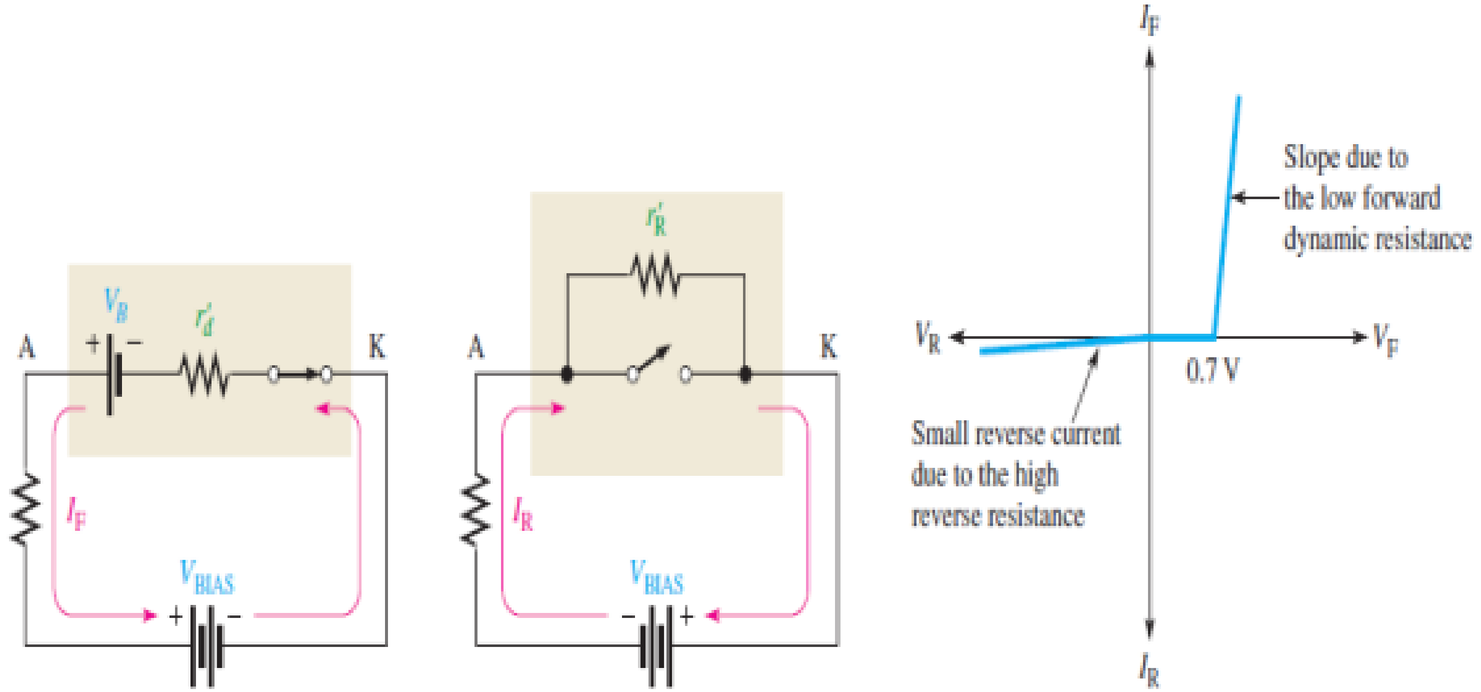
(c) Ideal V-I characteristic curve (blue)

2- The Practical Diode Model



3- The Complete Diode Model





(a) Forward bias (b) Reverse bias (c) V-I characteristic curve

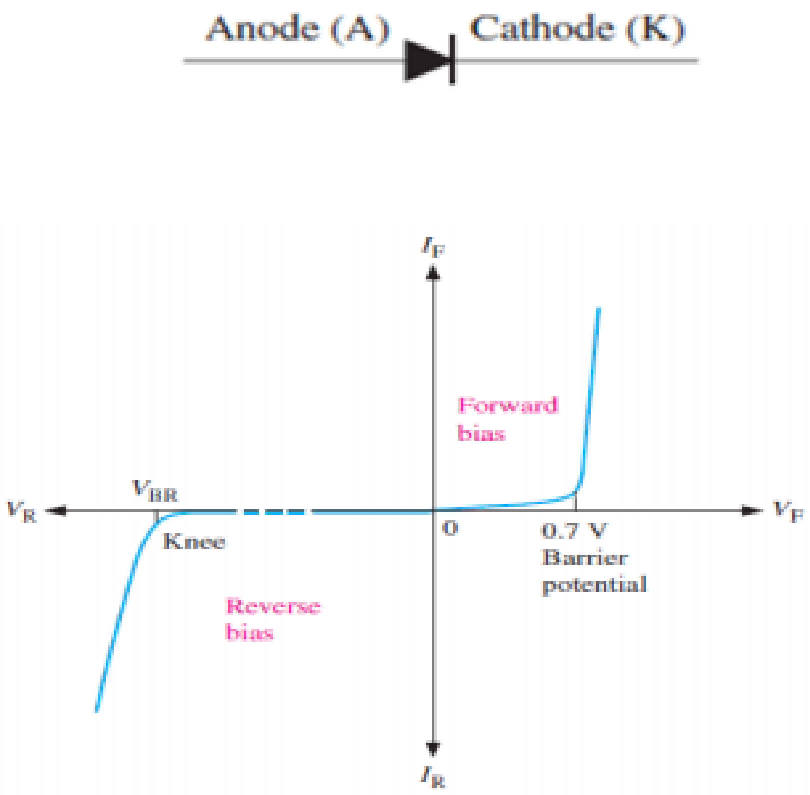
4- The Actual Diode Model

$$I_D = I_S\left(e^{\frac{V_D}{n v_t}} - 1\right)$$

I_s scale current

n constant

V_t thermal voltage =25mv



The complete V-I characteristic curve for a diode.


Thank you