# SNS COLLEGE OF TECHNOLOGY

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COIMBATORE-35
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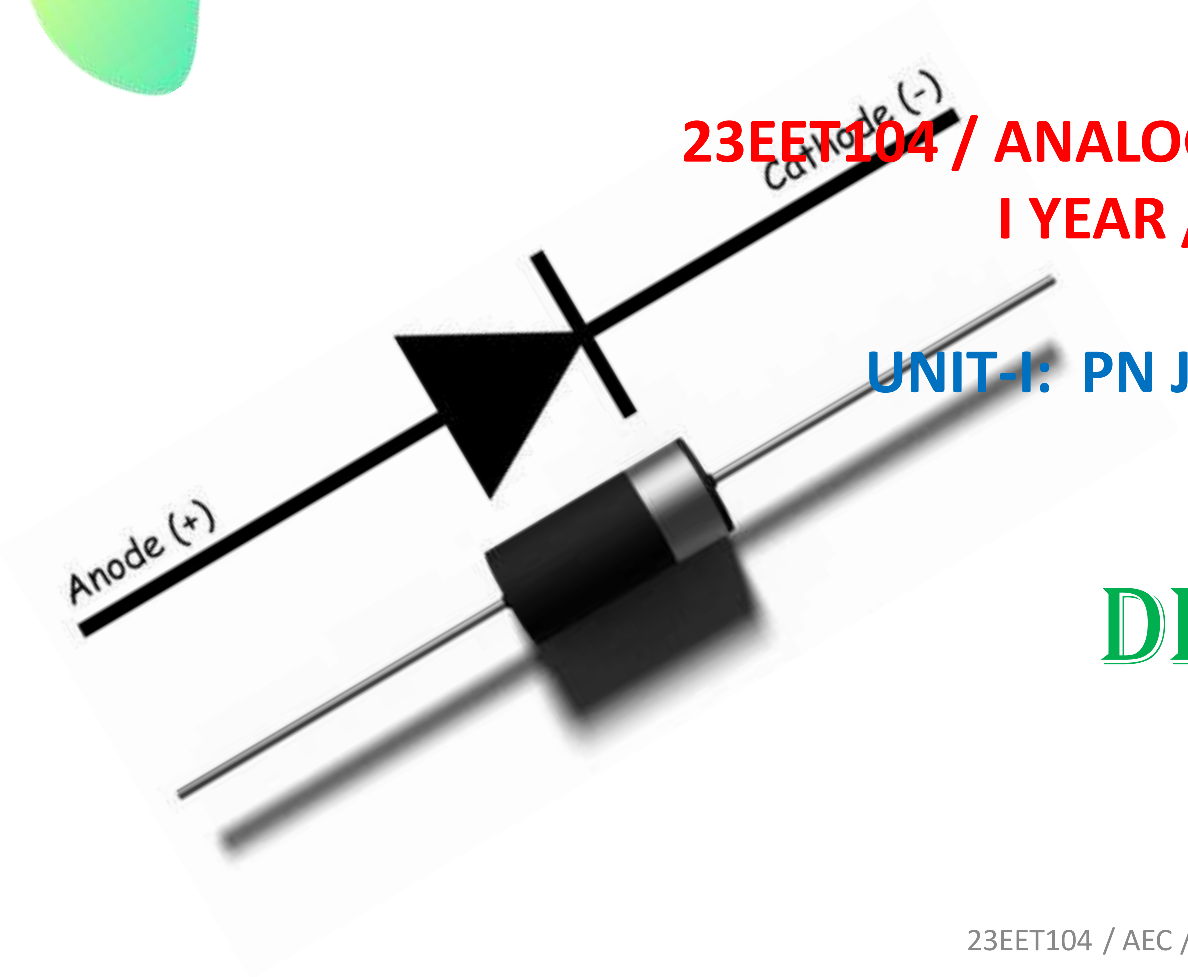



## 23EET104 / ANALOG ELECTRONICS CIRCUITS
## I YEAR / II SEMESTER

## UNIT-I: PN JUNCTION DEVICES

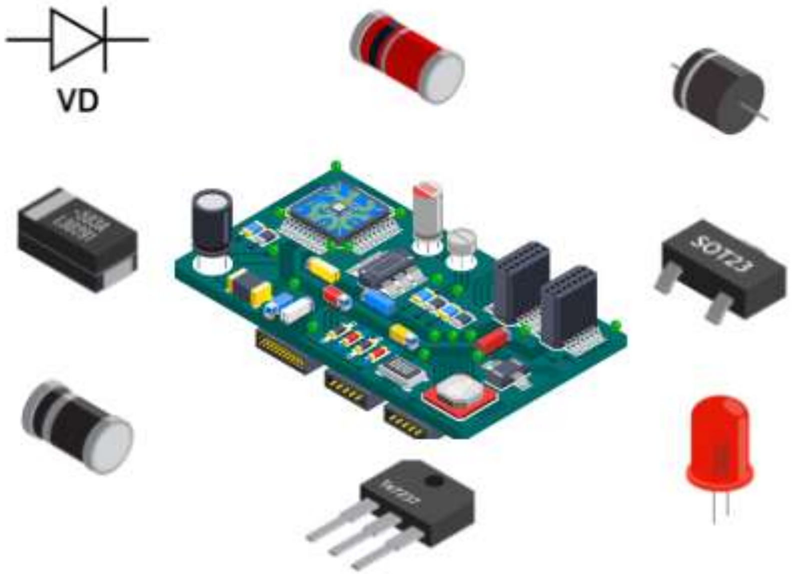
# DIODE

# TOPIC OUTLINE

- ✓ Introduction
- ✓ Diodes
- ✓ Electrical Properties of Solids
- ✓ Semiconductors
- ✓ PN Junctions
- ✓ Semiconductor Diodes
- ✓ Special-Purpose Diodes
- ✓ Diode Circuits

# Introduction

**A diode is defined as a two-terminal electronic component that only conducts current in one direction (so long as it is operated within a specified voltage level). An ideal diode will have zero resistance in one direction, and infinite resistance in the reverse direction.**



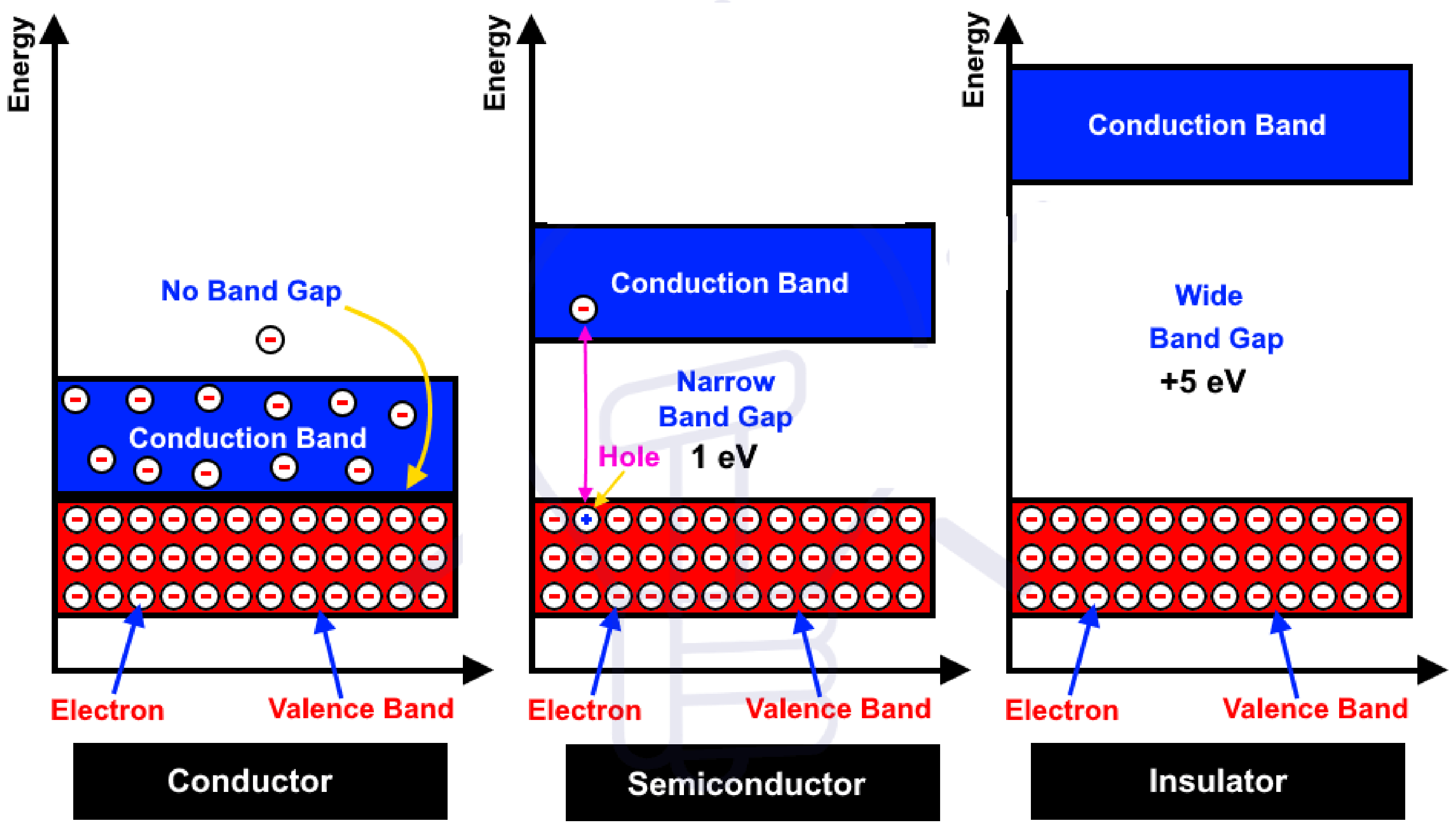
# Electrical Properties of Solids

- **Conductors**
  - e.g. copper or aluminium
  - have a cloud of free electrons (at all temperatures above absolute zero). If an electric field is applied electrons will flow causing an electric current
- **Insulators**
  - e.g. polythene
  - electrons are tightly bound to atoms so few can break free to conduct electricity

# Contd.,

- **Semiconductors**
  - e.g. silicon or germanium
  - at very low temperatures these have the properties of insulators
  - as the material warms up some electrons break free and can move about, and it takes on the properties of a conductor - albeit a poor one
  - however, semiconductors have several properties that make them distinct from conductors and insulators

# Contd.,



Energy
No Band Gap
Conduction Band
Electron
Valence Band
Conductor
Energy
Conduction Band
Narrow
Band Gap
Hole
1 eV
Electron
Valence Band
Semiconductor
Energy
Conduction Band
Wide
Band Gap
+5 eV
Electron
Valence Band
Insulator

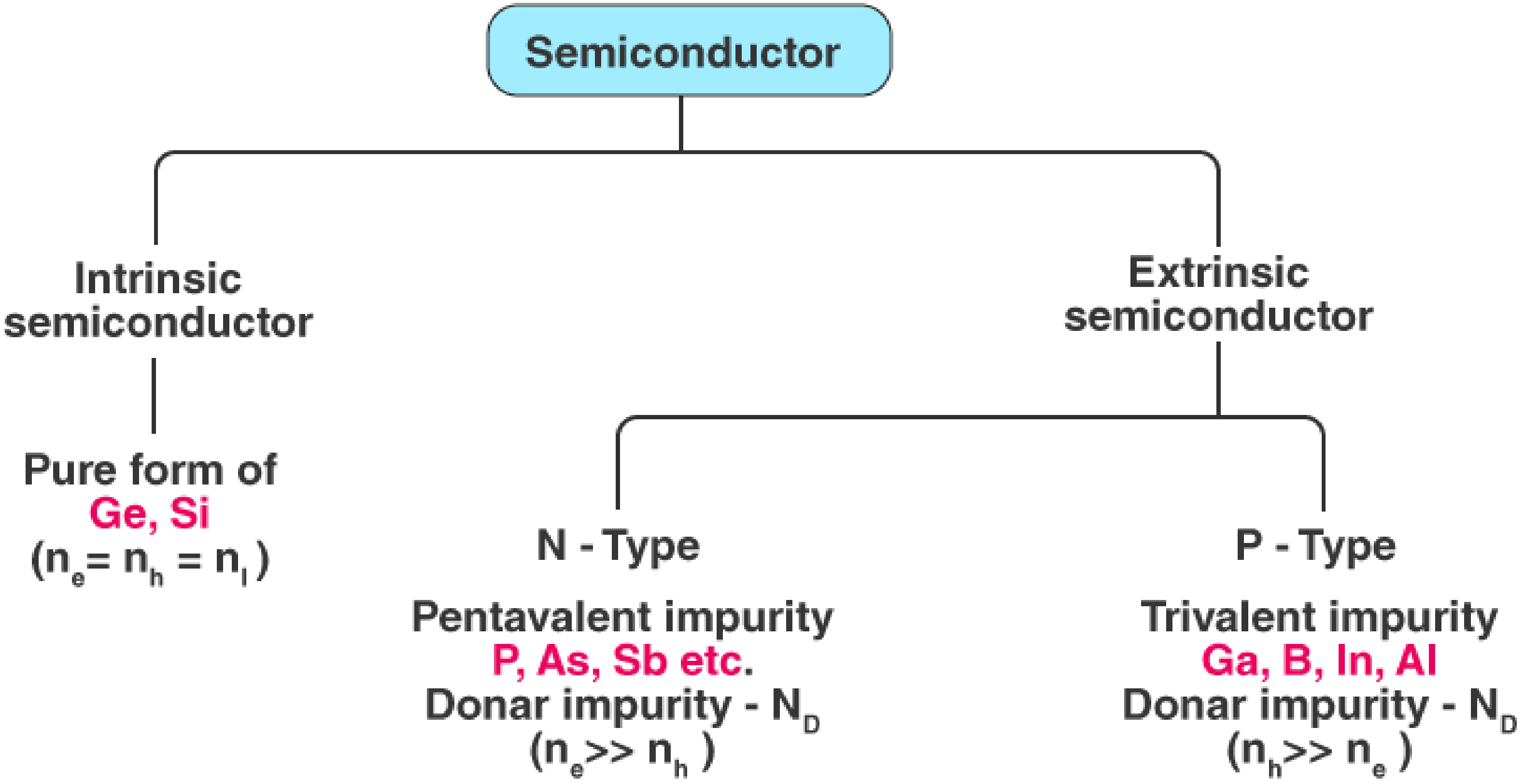
# Semiconductors

- **Pure semiconductors**
  - thermal vibration results in some bonds being broken generating **free electrons** which move about
  - these leave behind **holes** which accept electrons from adjacent atoms and therefore also move about
  - electrons are **negative charge carriers**
  - holes are **positive charge carriers**
- At room temperatures there are few charge carriers
  - *pure* semiconductors are poor conductors
  - this is **intrinsic conduction**

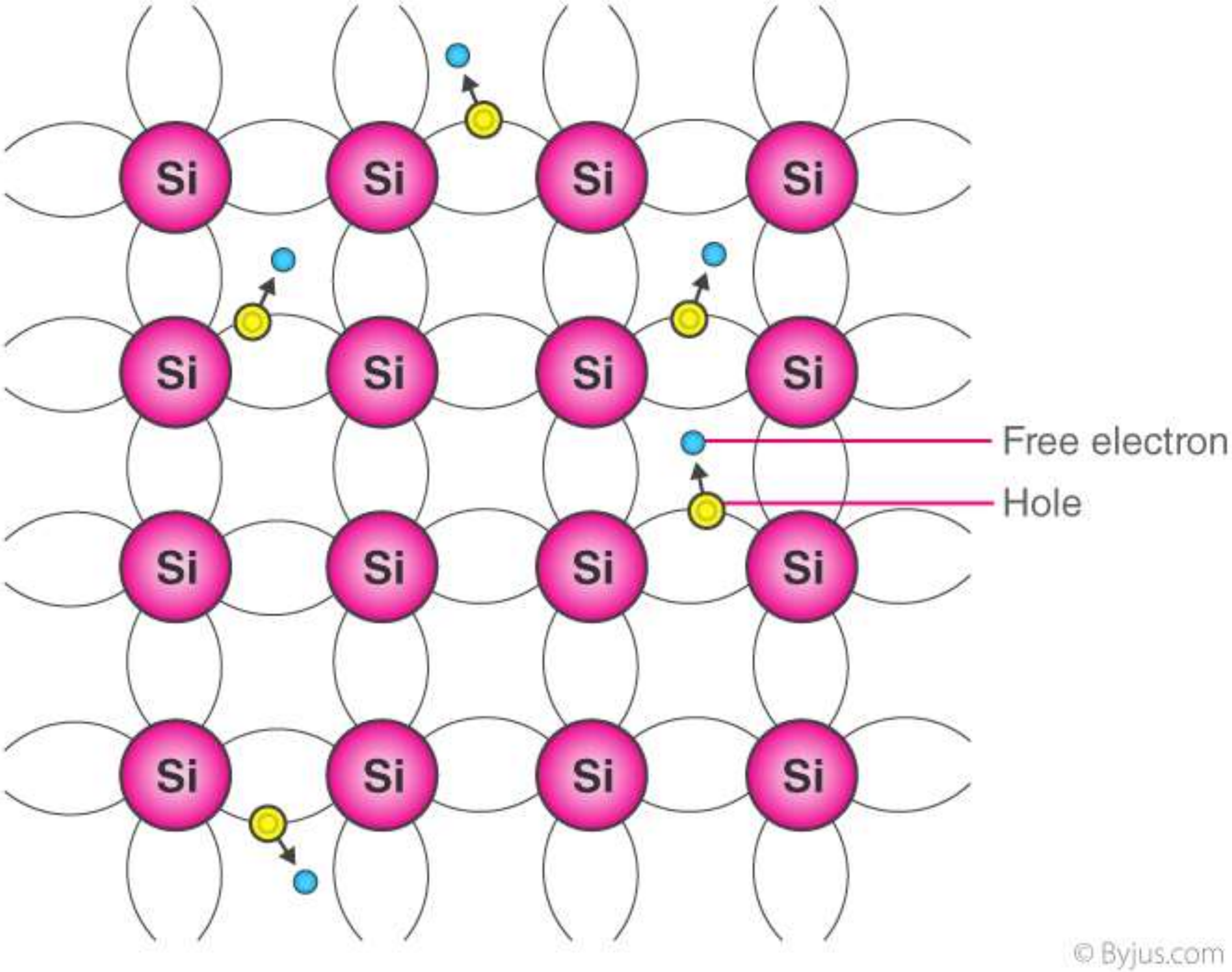
# Contd.,

- **Doping**
  - the addition of small amounts of impurities drastically affects its properties
  - some materials form an excess of *electrons* and produce an ***n*-type semiconductor**
  - some materials form an excess of *holes* and produce a ***p*-type semiconductor**
  - both *n*-type and *p*-type materials have much greater conductivity than pure semiconductors
  - this is **extrinsic conduction**

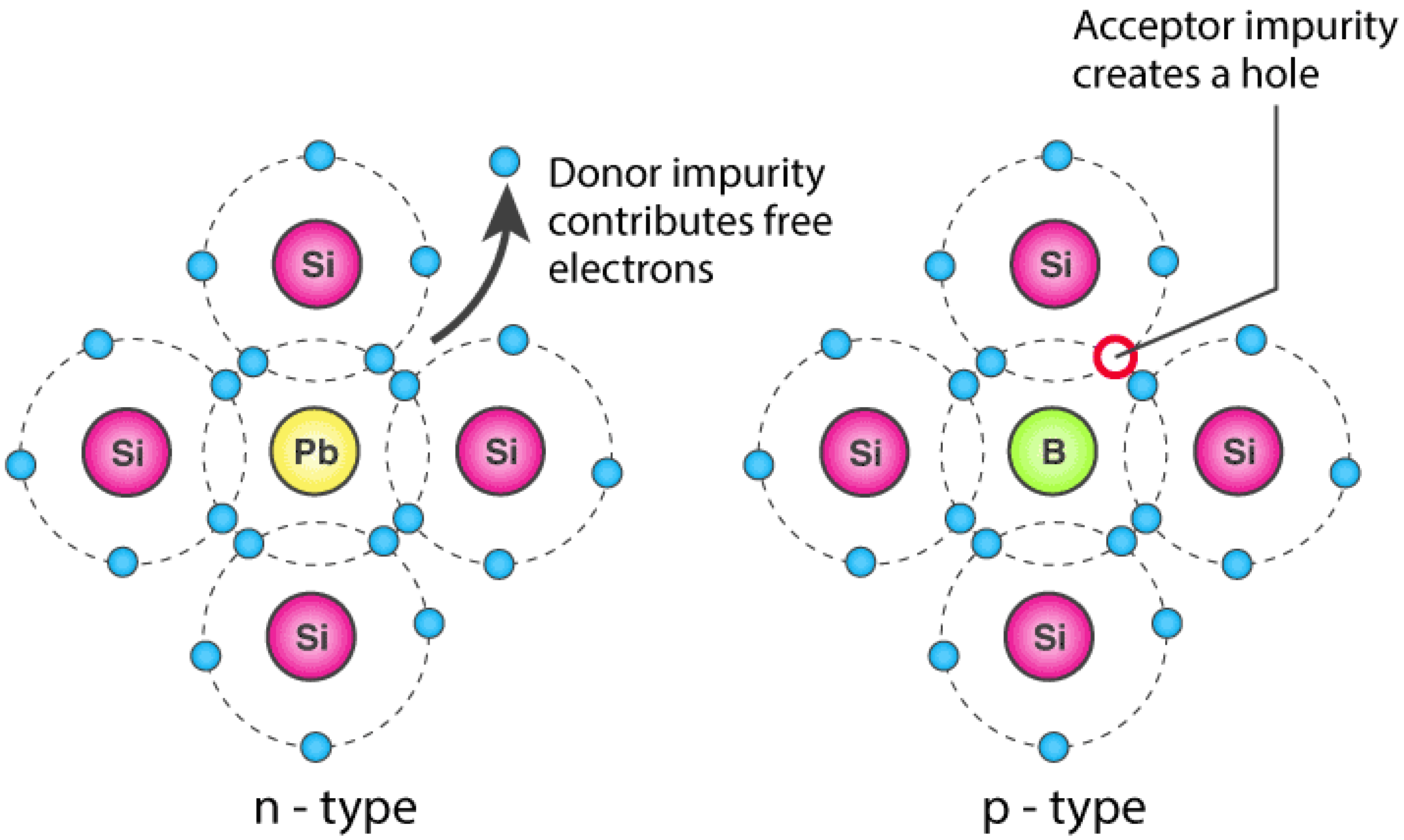
# Contd.,


Semiconductor
Intrinsic semiconductor
Pure form of
Ge, Si
$(n_e = n_h = n_i)$
Extrinsic semiconductor
N - Type
Pentavalent impurity
P, As, Sb etc.
Donar impurity - $N_D$
$(n_e >> n_h)$
P - Type
Trivalent impurity
Ga, B, In, Al
Donar impurity - $N_D$
$(n_h >> n_e)$

# INTRINSIC SEMICONDUCTORS

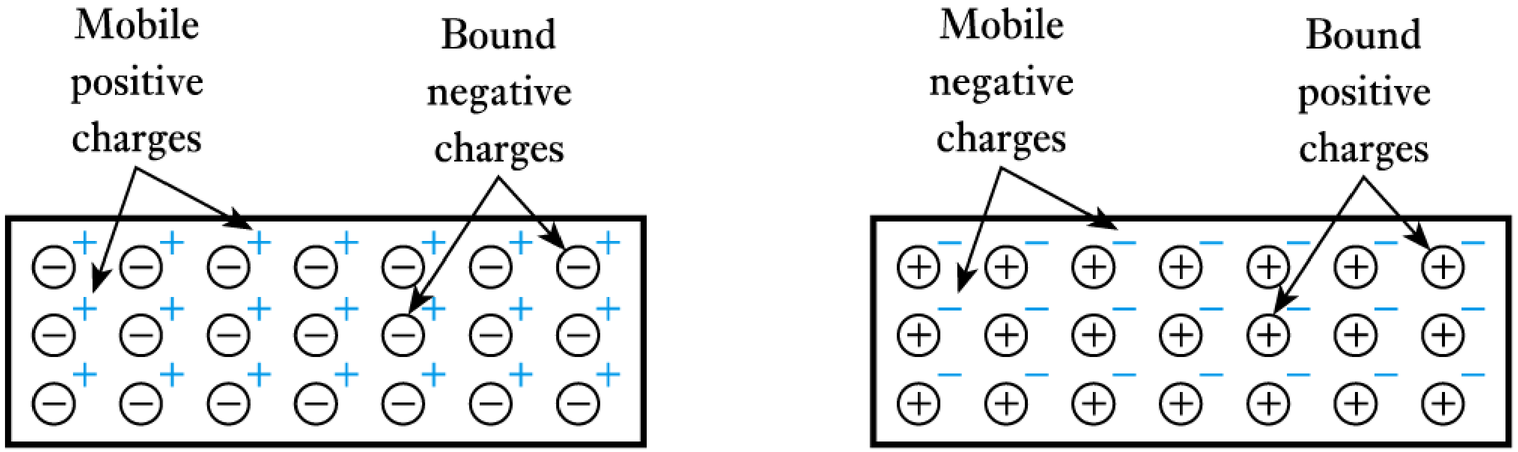


# EXTRINSIC SEMICONDUCTORS



# Working principle:

- The dominant charge carriers in a doped semiconductor (e.g. electrons in *n*-type material) are called **majority charge carriers**. Other type are **minority charge carriers**
- The overall doped material is electrically neutral



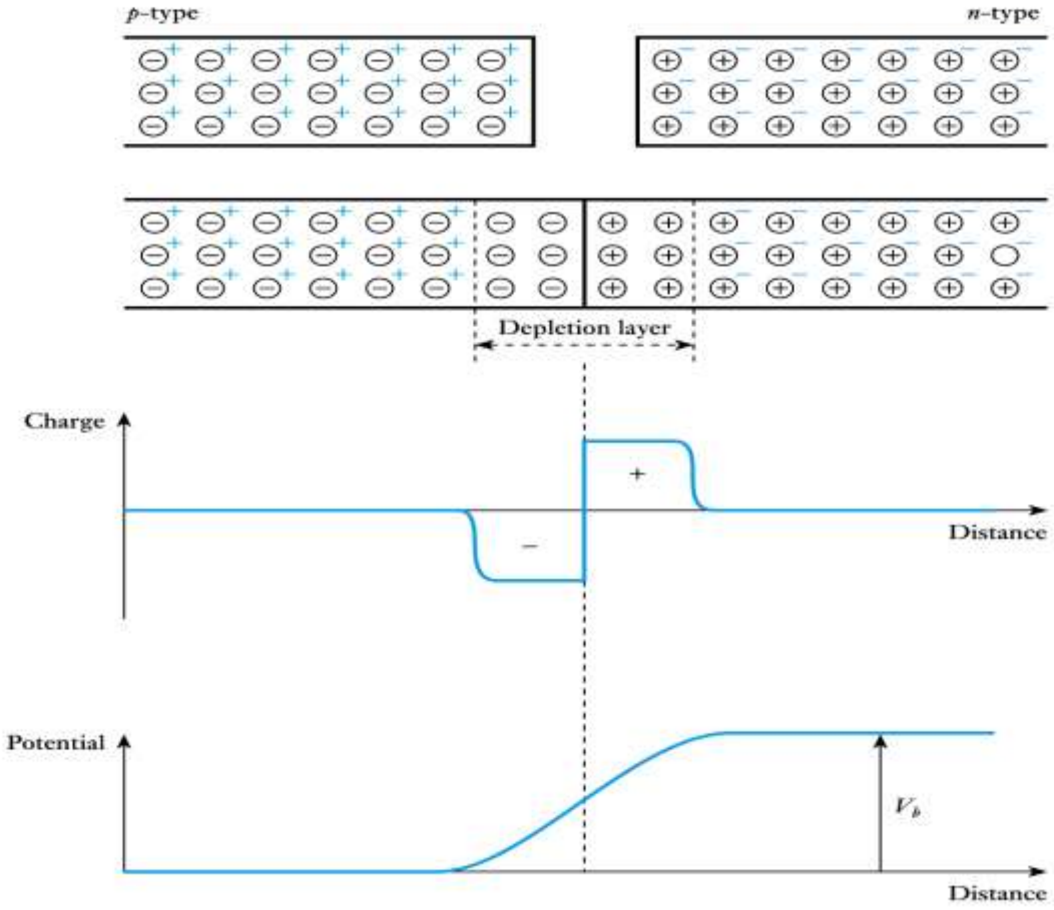

(a) *p*-type semiconductor (b) *n*-type semiconductor

# pn Junctions

- When *p*-type and *n*-type materials are joined this forms a ***pn* junction**
  - majority charge carriers on each side diffuse across the junction where they combine with (and remove) charge carriers of the opposite polarity
  - hence around the junction there are few free charge carriers and we have a **depletion layer** (also called a **space-charge layer**)

# Contd.,

- The diffusion of positive charge in one direction anc negative charge in the othe produces a charge imbalan
  - this results in a **potential barrier** across the junction



# Working principle:

- **Potential barrier**
  - the barrier opposes the flow of *majority* charge carriers and only a small number have enough energy to surmount it
    - this generates a small **diffusion current**
  - the barrier encourages the flow of *minority* carriers and any that come close to it will be swept over
    - this generates a small **drift current**
  - for an isolated junction these two currents must balance each other and the net current is zero

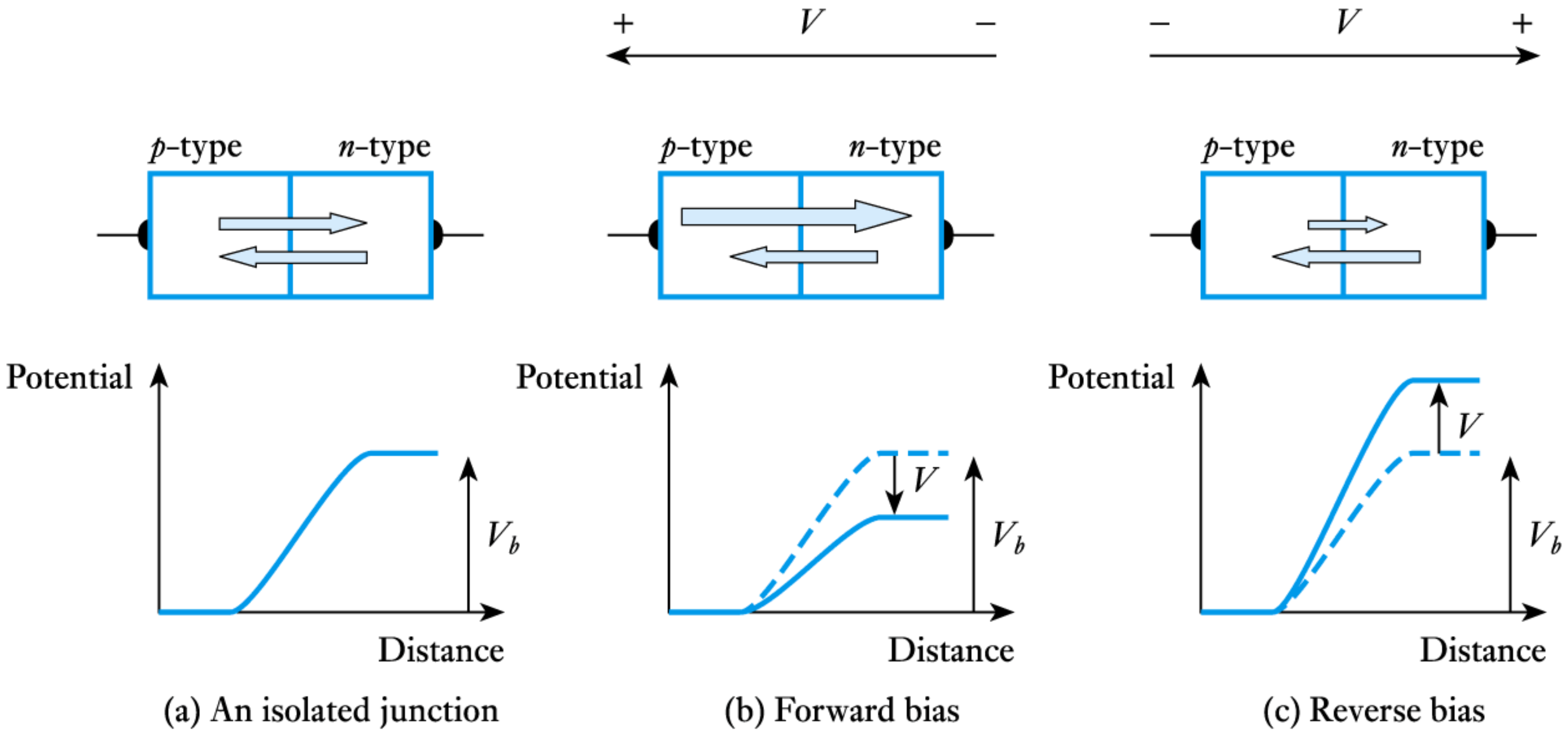
# Working principle:

- **Forward bias**
  - if the *p*-type side is made *positive* with respect to the *n*-type side the height of the barrier is reduced
  - more majority charge carriers have sufficient energy to surmount it
  - the diffusion current therefore increases while the drift current remains the same
  - there is thus a net current flow across the junction which increases with the applied voltage

# Working principle:

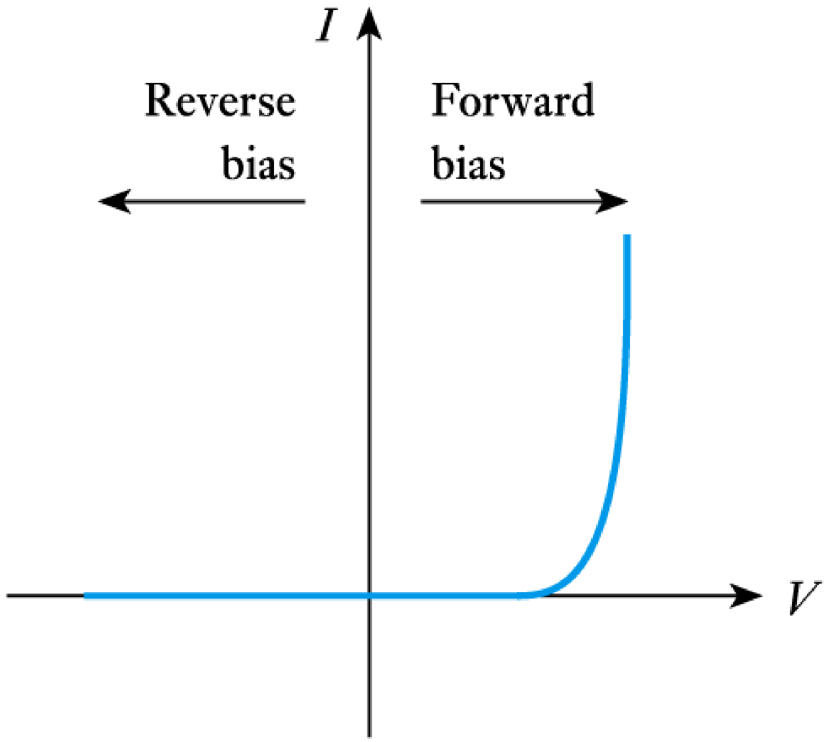
- **Reverse bias**
  - if the *p*-type side is made *negative* with respect to the *n*-type side the height of the barrier is increased
  - the number of majority charge carriers that have sufficient energy to surmount it rapidly decreases
  - the diffusion current therefore vanishes while the drift current remains the same
  - thus the only current is a small leakage current caused by the (approximately constant) drift current
  - the leakage current is usually negligible (a few nA)

## Currents in a *pn* junction



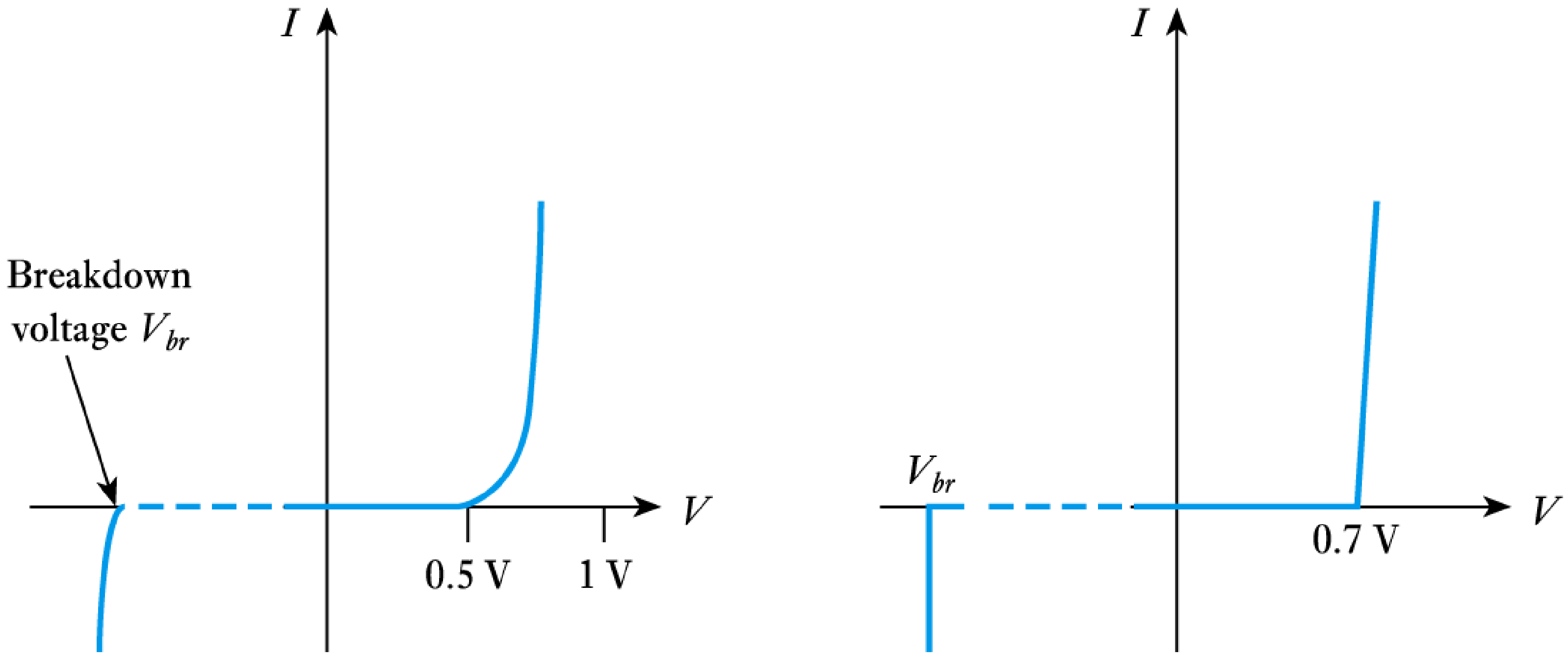
# VI Characteristics

- **Forward and reverse currents**



# VI Characteristics

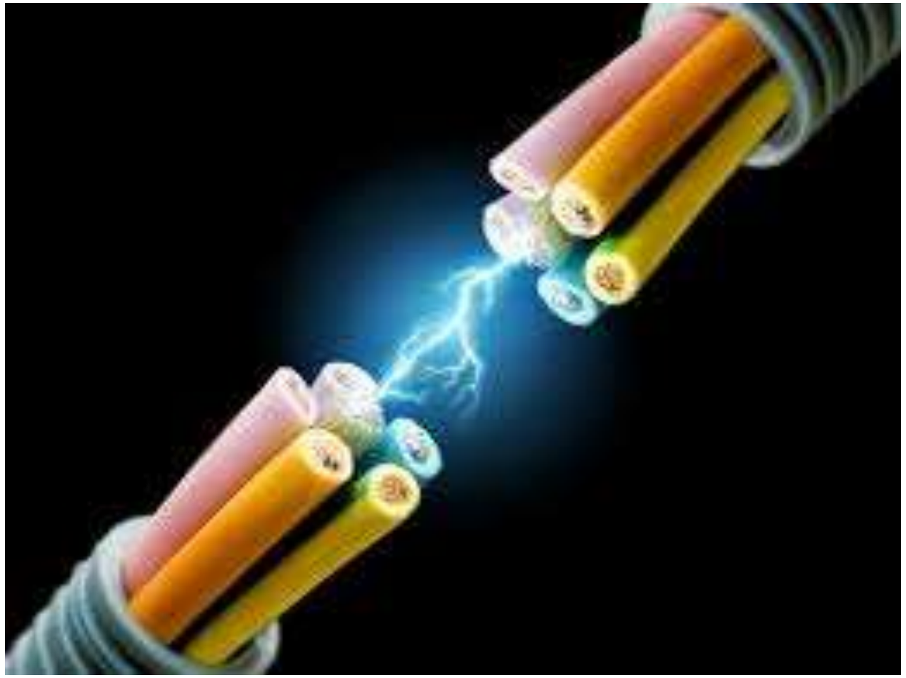
- **Turn-on** and **breakdown voltages** for a silicon




(a) A silicon diode

(b) Straight-line approximation to silicon diode characteristics

# RECAP….



# …THANK YOU