Basics of Electronics Engineering (EC102)

Contents

- Introduction to Electronics
- Semiconductor Theory
- Review of PN junction operation
- Plot and analyse V-I Characteristics of PN-Junction Diode

Semiconductor Diodes and Applications

- **Introduction to Electronics**
- Semiconductor Theory
- Review of PN junction operation
- Plot and analyse V-I Characteristics of PN-Junction Diode

Introduction to Electronics

- Electronics is the branch of science and engineering dealing with the theory and use of a class of devices in which electrons are transported through a vacuum, gas or semiconductor.
- Electron + Mechanics = Electronics (Study of behavior of the electron when it is subjected to externally applied fields)

- Electronics is that field of science and engineering which deals with electronic devices and their utilisation.

- Electron device is device in which conduction takes place by the movement of electrons through a vacuum, a gas or a semiconductor.

Video link on history and evolution of electronics

Video 1: What is electronics ? History of Electronics.
https://www.youtube.com/watch?v=keOw1sdsw3U&t=145s

Time to test ?

Q. Electronics is that branch of engineering which deals with the application of

A. high current machines
B. production of electronic components
C. electronic devices
D. fission of uranium nuclei

Answer ???

Applications of Electronics

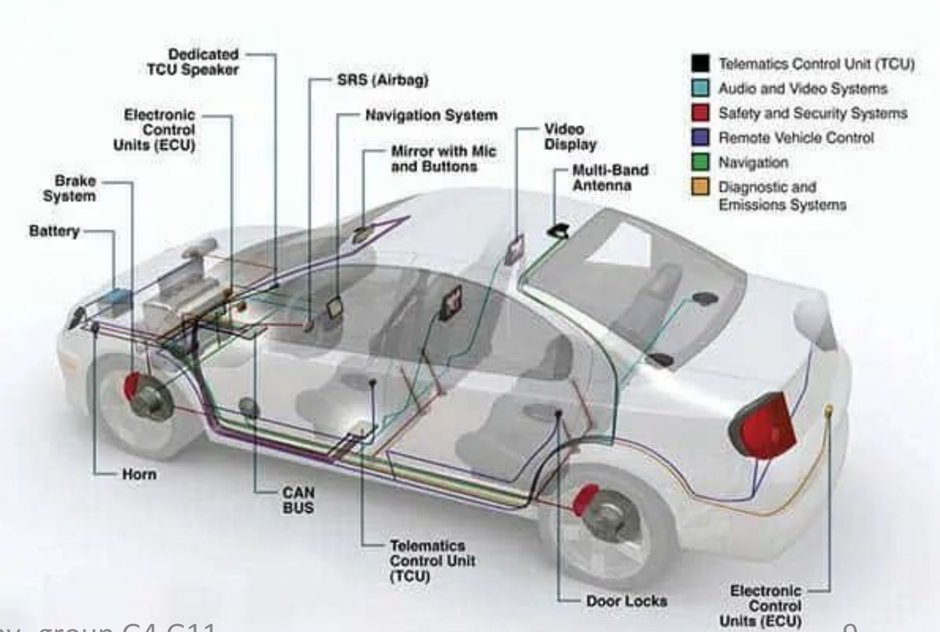
- Consumer Electronics

- Industrial Electronics

Applications of Electronics

- Defense

- Automotive



Applications of Electronics

- Medical

- Environmental monitoring

Modern trends in Electronics

- Augmented and Virtual Reality in Electronic Manufacturing
- Robotics & Automation
- IoT Technology Driving Smart Appliances
- Artificial Intelligence
- Computer Vision

Non Immersive

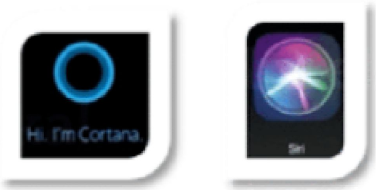
Jogging with a VR TV

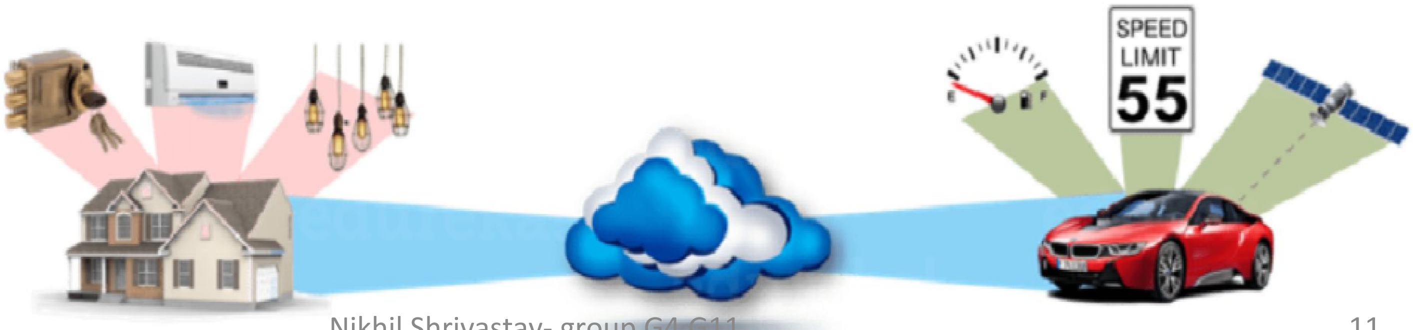
Fully Immersive

Immersive VR Gaming

Chat-bots

Virtual Assistants





video link on electronics applications

https://www.youtube.com/watch?v=7y5_guC9R
-s

Are you Awake?

Name any one application of electronics in each of the following category:

a) communication and entertainment industry.

b) Defence

c) Industry

d) Medical sciences

e) Instrumentation

Evolution of Electronics

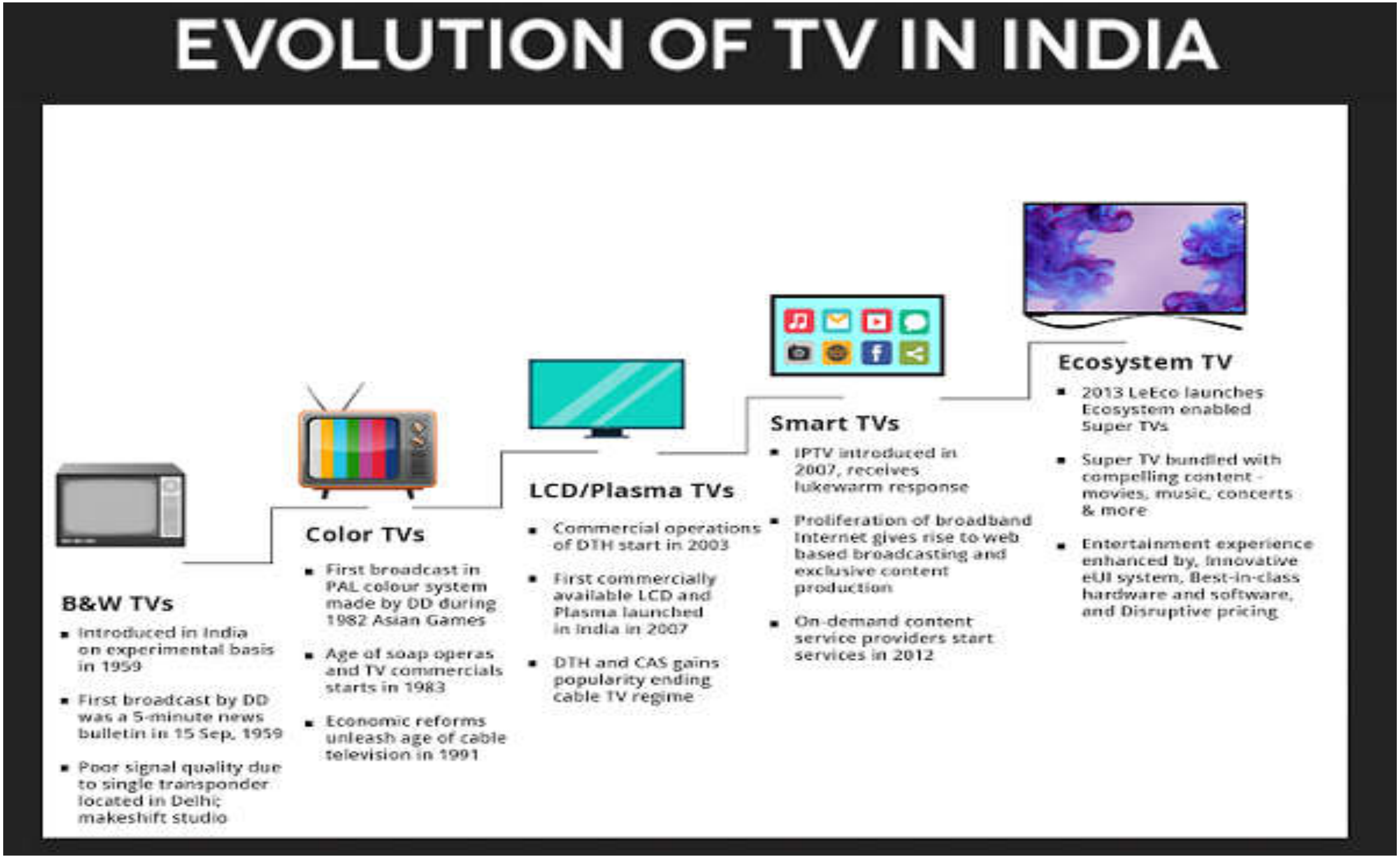
- 1784 (Charles Augustin Coulomb –Electrical Charge)
- 1799 (Alessandro Volta –Voltage)
- 1827 (George Simon Ohm- Resistance)
- 1876 (Alexander Graham Bell-Telephone)
- 1895 (Marconi-Radio)
- 1904 (Ambrose Fleming – Vacuum Tube)
- **1925 (John Logie Baird – Television)**
- 1939 (Russell Ohl – PN Junction Diode)
- 1948 (William Schockley, John Bardeen and Watter Brattain-Transistor)
- 1958 (Jack Kilby – Integrated Circuit)
- 1971 (Robert Noyce and Gordon Moore-Microprocessor)

Video link on evolution of electronics

Video 3: https://www.youtube.com/watch?v=Cto8IXH0a_o

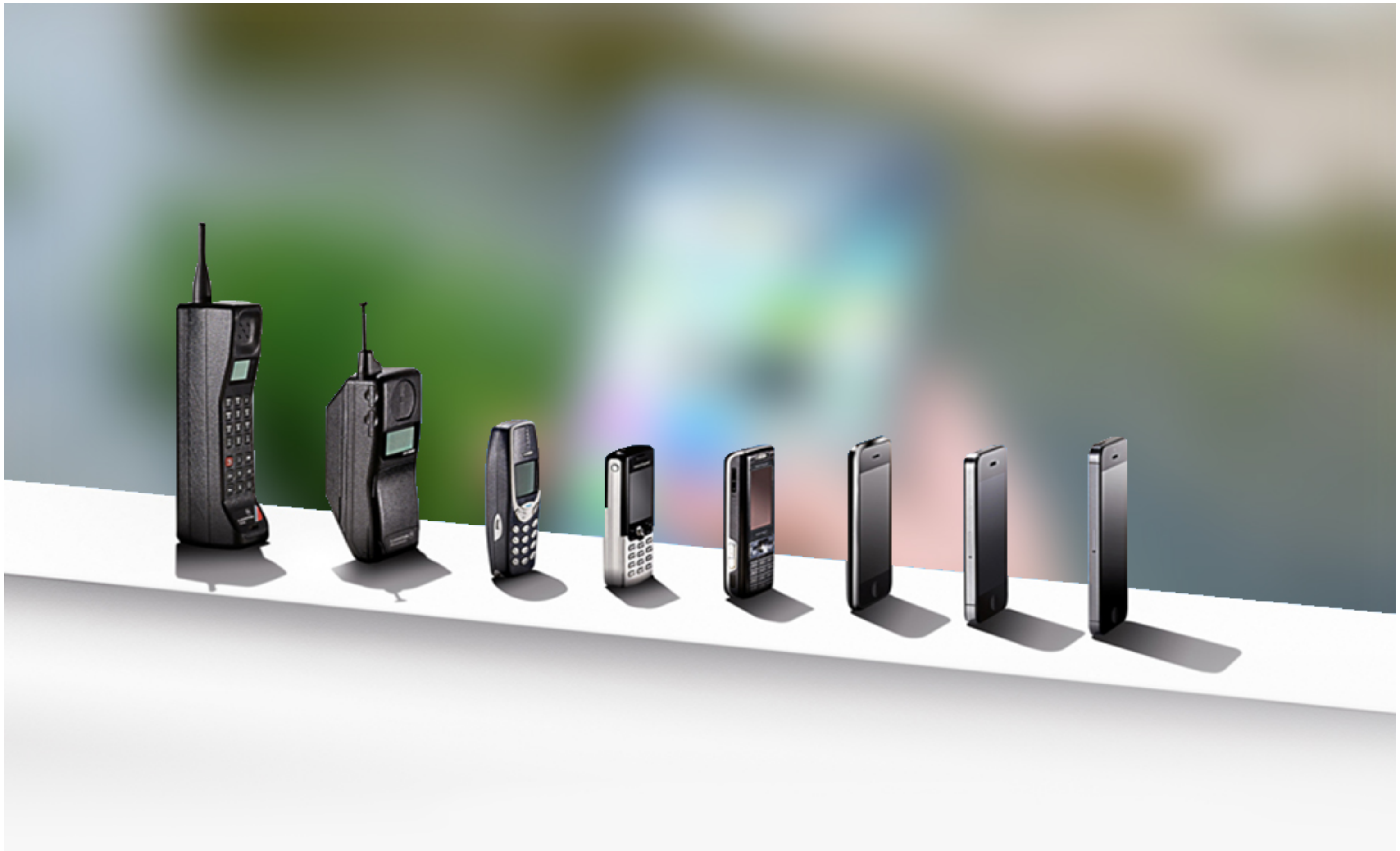
Pause to think and notice

- Majority of devices (For example TV) in use today were invented decades ago in 1925
- Actual thing is **steady improvement in construction technique and application of those devices** rather than development of new elements and fundamentally new designs **(see fig. evolution of TV in next slide)**
- Major change have been in the **understanding of how these devices work and their full range of capabilities.**

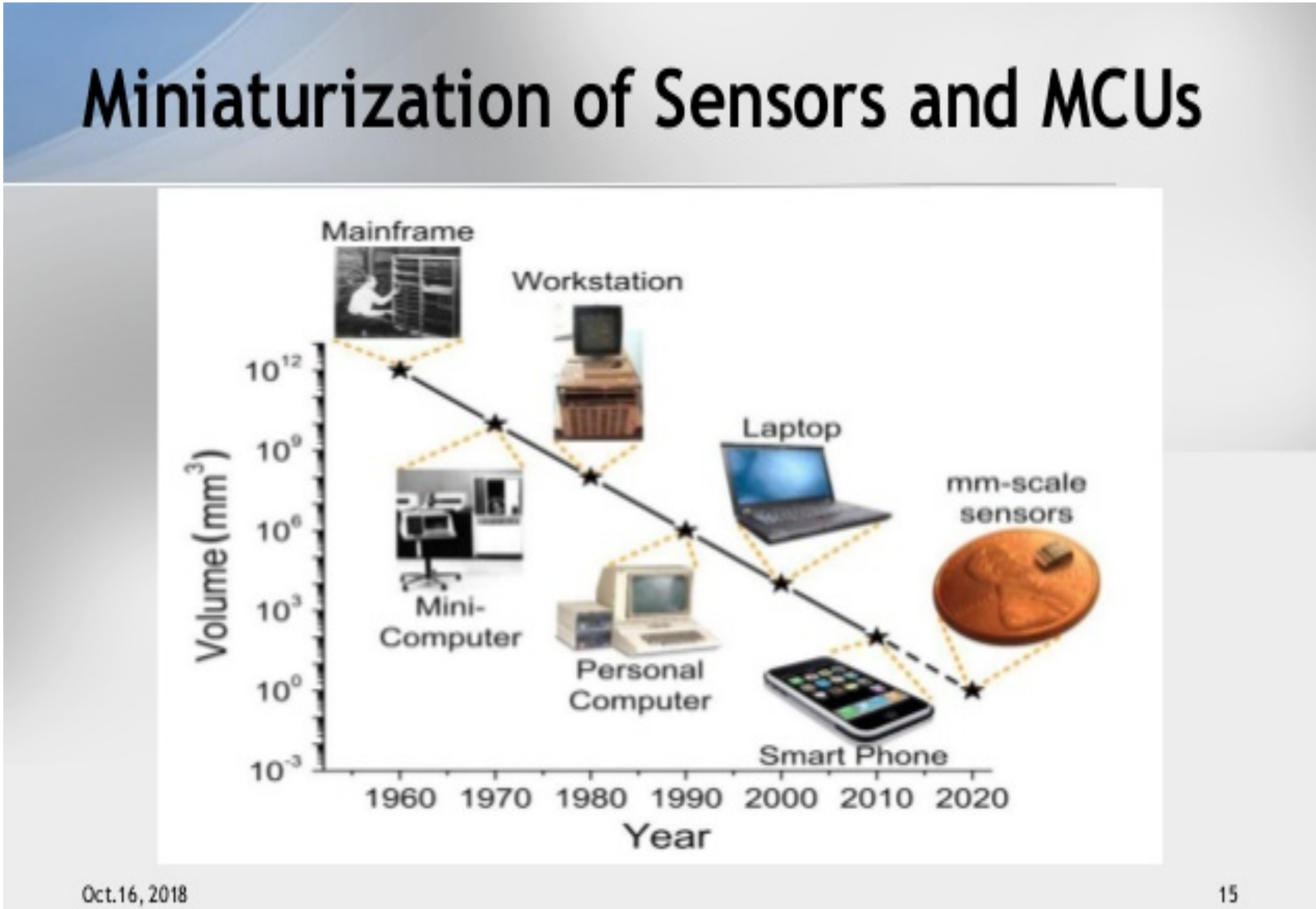

EVOLUTION OF TV IN INDIA
B&W TVs
Introduced in India on experimental basis in 1959
First broadcast by DD was a 5-minute news bulletin in 15 Sep, 1959
Poor signal quality due to single transponder located in Delhi; makeshift studio
Color TVs
First broadcast in PAL colour system made by DD during 1982 Asian Games
Age of soap operas and TV commercials starts in 1983
Economic reforms unleash age of cable television in 1991
LCD/Plasma TVs
Commercial operations of DTH start in 2003
First commercially available LCD and Plasma launched in India in 2007
DTH and CAS gains popularity ending cable TV regime
Smart TVs
IPTV introduced in 2007, receives lukewarm response
Proliferation of broadband Internet gives rise to web based broadcasting and exclusive content production
On-demand content service providers start services in 2012
Ecosystem TV
2013 LeEco launches Ecosystem enabled Super TVs
Super TV bundled with compelling content - movies, music, concerts & more
Entertainment experience enhanced by, Innovative eUI system, Best-in-class hardware and software, and Disruptive pricing

Miniaturization

- Modern Electronic devices now appear on wafers thousand of times smaller than the single element of earlier networks.



Miniaturization



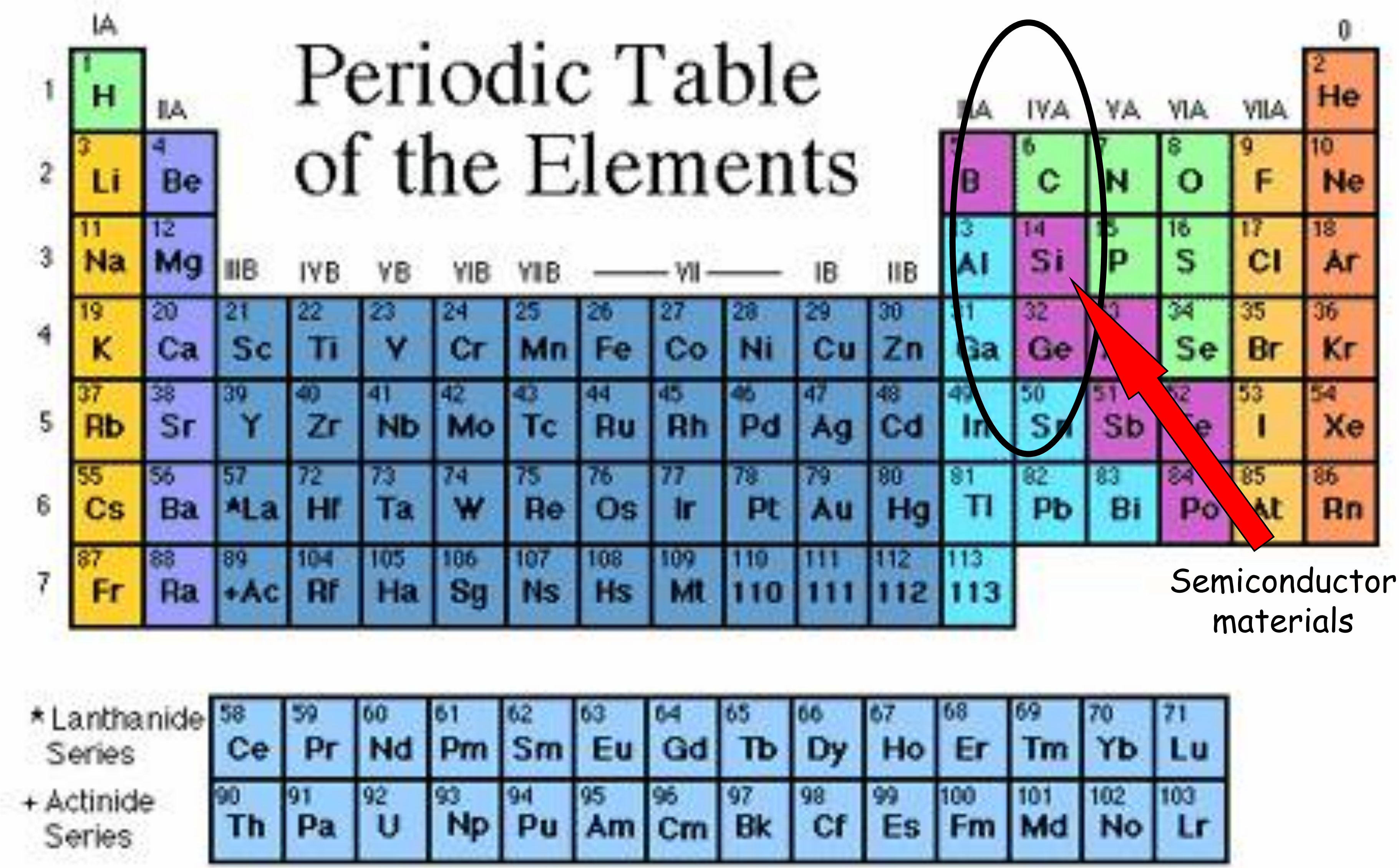
video on miniaturization

- video link : https://www.youtube.com/watch?v=GnmASQCV1aM

Semiconductors: Base of Electronics Industry

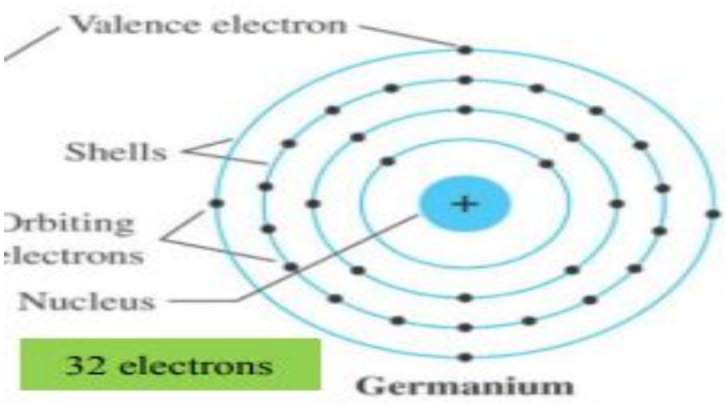
- The construction of every electronic device begins with semiconductor material of highest quality.
- The semiconductors fall somewhere midway between conductors and insulators.
- The three semiconductors used most frequently in construction of electronic devices are Ge, Si and GaAs

Introduction to Semiconductors



Semiconductor materials

Germanium (atomic number 32: 2,8,18,4)



- It has four valence electrons so known as tetravalent.
- It was relatively easy to find and was available in fairly large quantities.
- Easy to refine to obtain high levels of purity
- Ge was first semiconductor to be used to construct Diode in 1939 and transistor in 1947

Drawback:

- It has low level of reliability due to its sensitivity to changes in temperature

Silicon (atomic number 14: 2,8,4)

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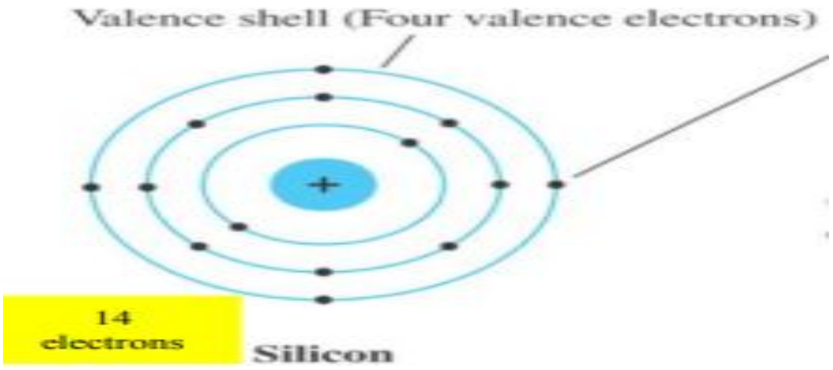
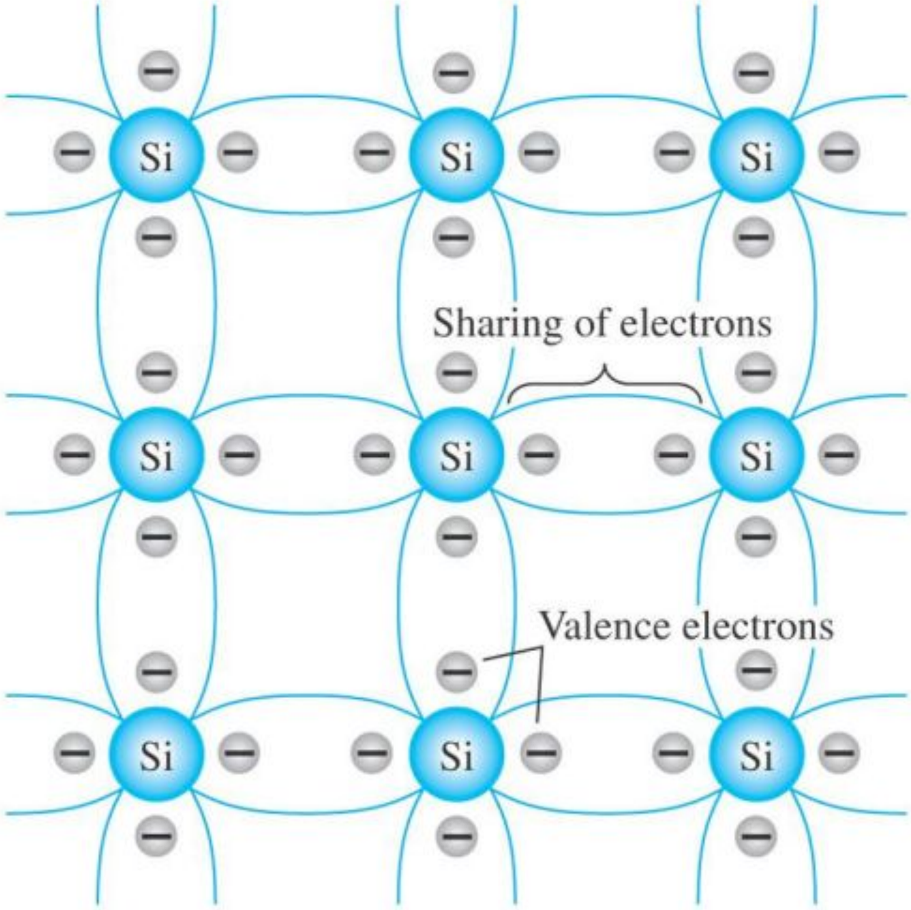


- It has four valence electrons so known as tetravalent.
- It is better than germanium due to its less temperature sensitivity and it is one of the most abundant material on earth.
- So it becomes leading semiconductor material for electronic components and ICs
- In 1954, First silicon transistor was introduced

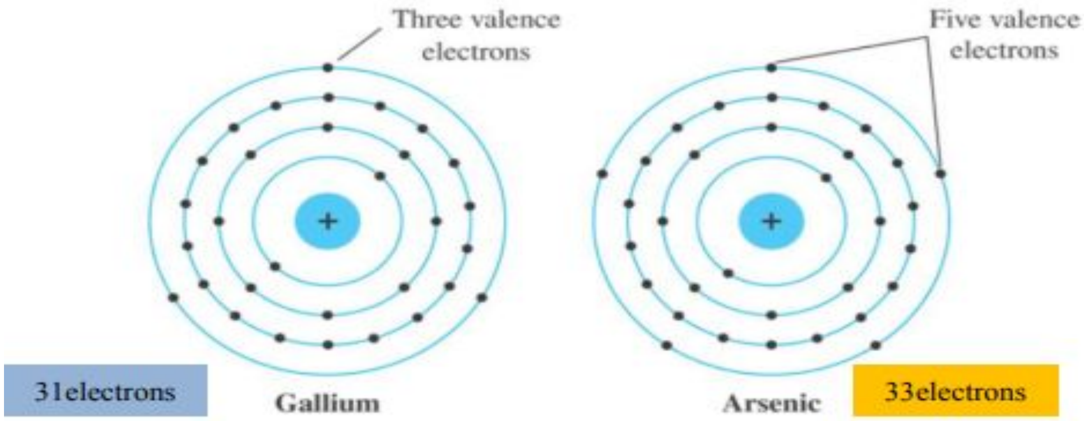
Covalent Bonding of pure silicon crystal



Growing demands of Industry

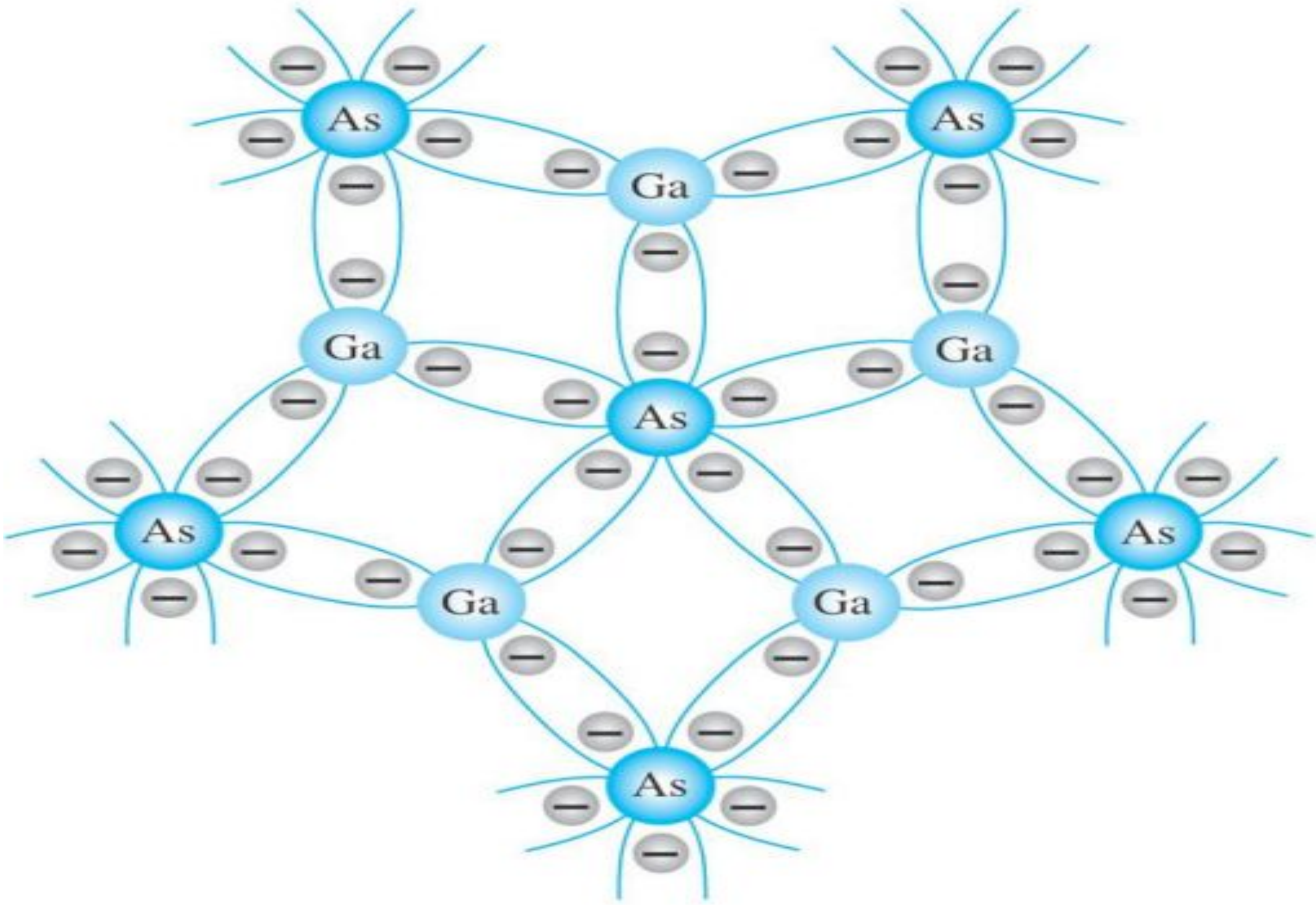
- The field of electronics became increasingly sensitive to issues of speed.
- Computers were operating at higher and higher speeds
- Communication systems were operating at higher levels of performance.
- So new semiconductor material was required

Gallium Arsenide



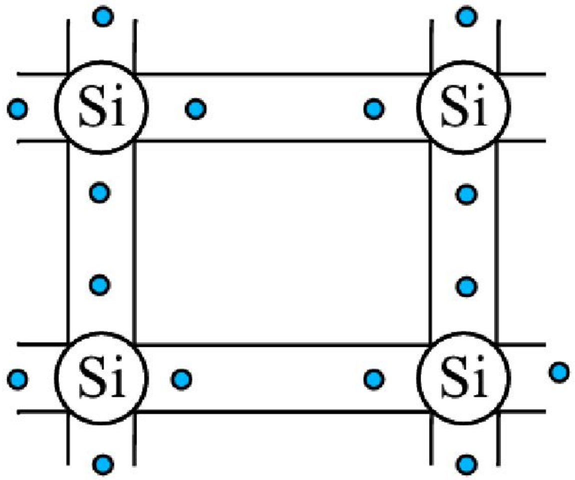
- It is compound semiconductor which is constructed from two semiconductor materials Gallium (atomic number 31: 2,8,18,3) trivalent and Arsenic (atomic number 33:2,8,18,5) pentavalent
- GaAs transistor was developed in early 1970’s whose speed of operation is fast upto five times that of silicon.
- Drawback : difficult to manufacture and expensive

Covalent Bonding of GaAs



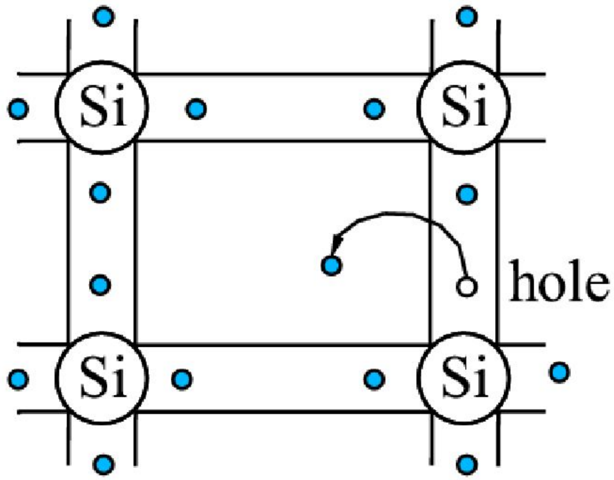
Electrons and Holes

Si and Ge are tetravalent elements – each atom of Si (or Ge) has 4 valence electrons in its crystal matrix



T=0 all electrons are bound in covalent bonds

no carriers available for conduction.



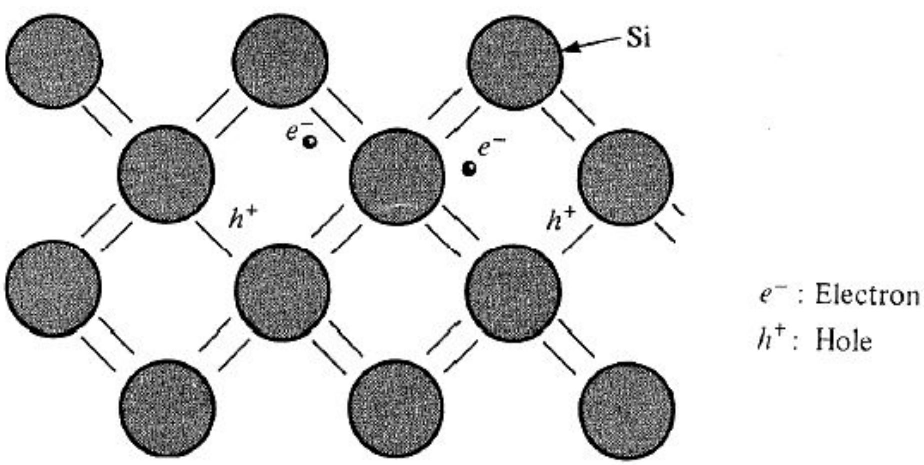
For T> 0 thermal fluctuations can break the electrons free, creating electron-hole pairs

Both can move throughout the lattice and therefore conduct current.

Intrinsic Material

A pure semiconductor crystal with no impurities or lattice defects is called an ***intrinsic*** semiconductor.

- At T=0 K, No charge carriers.
- Valence band is filled with electrons.
- Conduction band is empty.

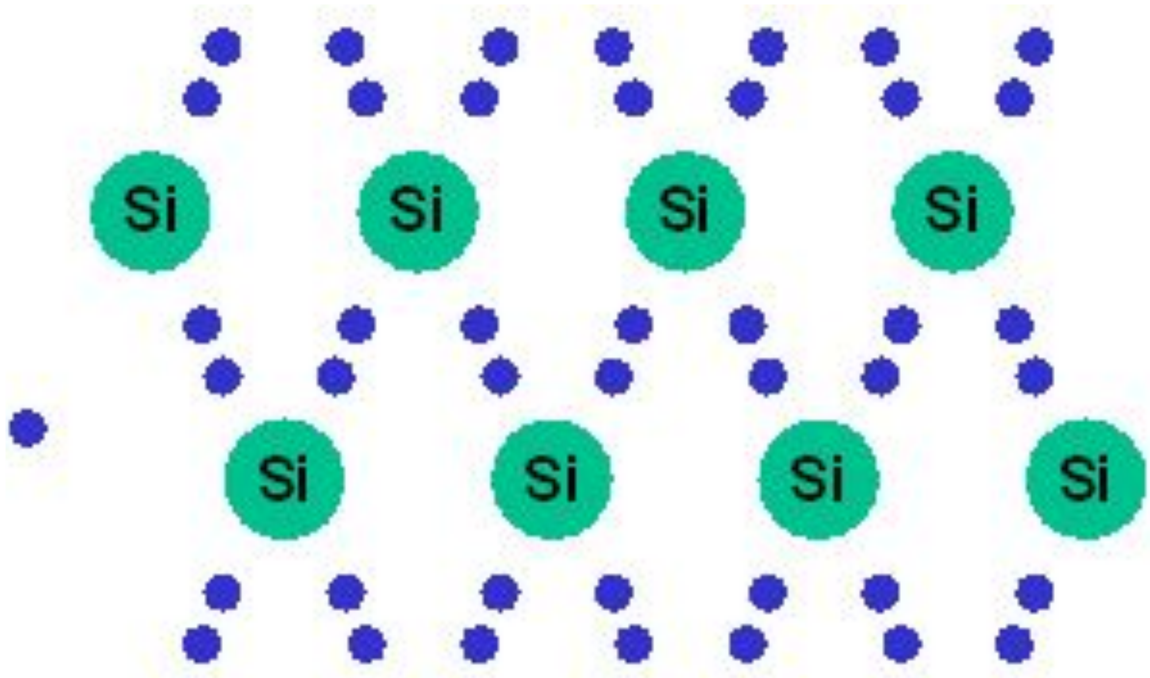


Electron-hole pairs in the covalent bonding model in the Si crystal.

- At T>0, Electron-hole pairs are generated.
- EHPs are the only charge carriers in *intrinsic material.*
- Since electron and holes are created in pairs – the electron concentration in conduction band, *n* (electron/cm^3) is equal to the concentration of holes in the valence band, *p* (holes/cm^3).
- Each of these intrinsic carrier concentrations is denoted n_i.

Thus for intrinsic materials $n=p=n_i$

Intrinsic Silicon

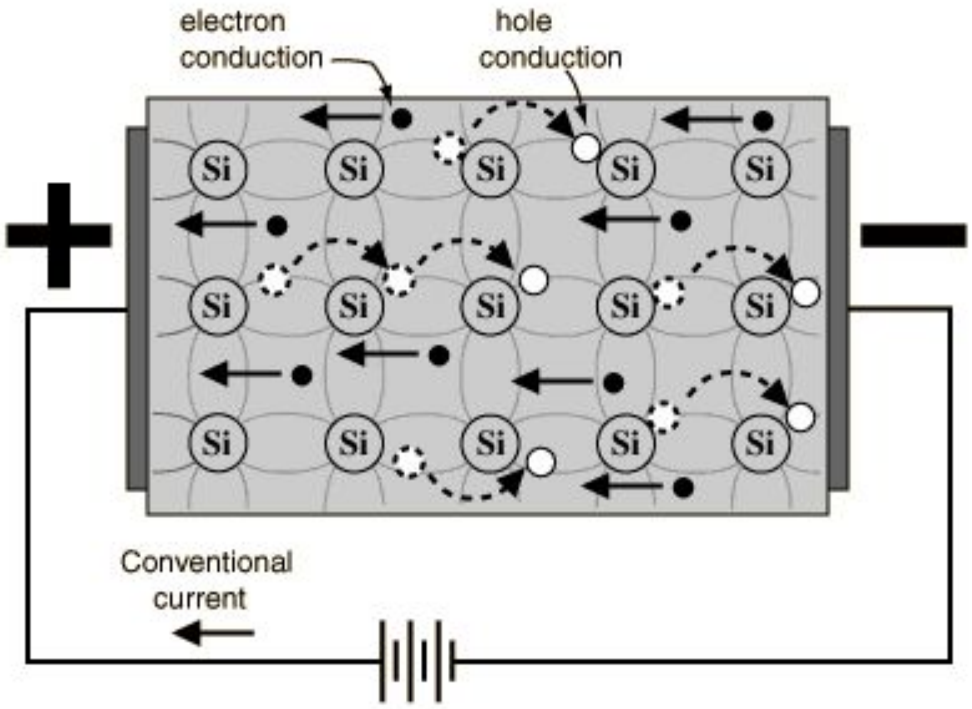


At any temperature above absolute zero temperature, there is a finite probability that an electron in the lattice will be knocked loose from its position.

Intrinsic carriers and relative mobility

- The free electrons in a material due to external causes are known as intrinsic carriers.
- Number of intrinsic carriers in popular semiconductors are arranged in descending order as Ge>GaAs>Si (as per the internal properties)
- But electronic devices have fast response time due to maximum relative mobility of free carriers
- Order of relative mobility is GaAs>Ge>Si

Current Flow through intrinsic semiconductor



If a voltage is applied, then both the electron and the hole can contribute to a small current flow.

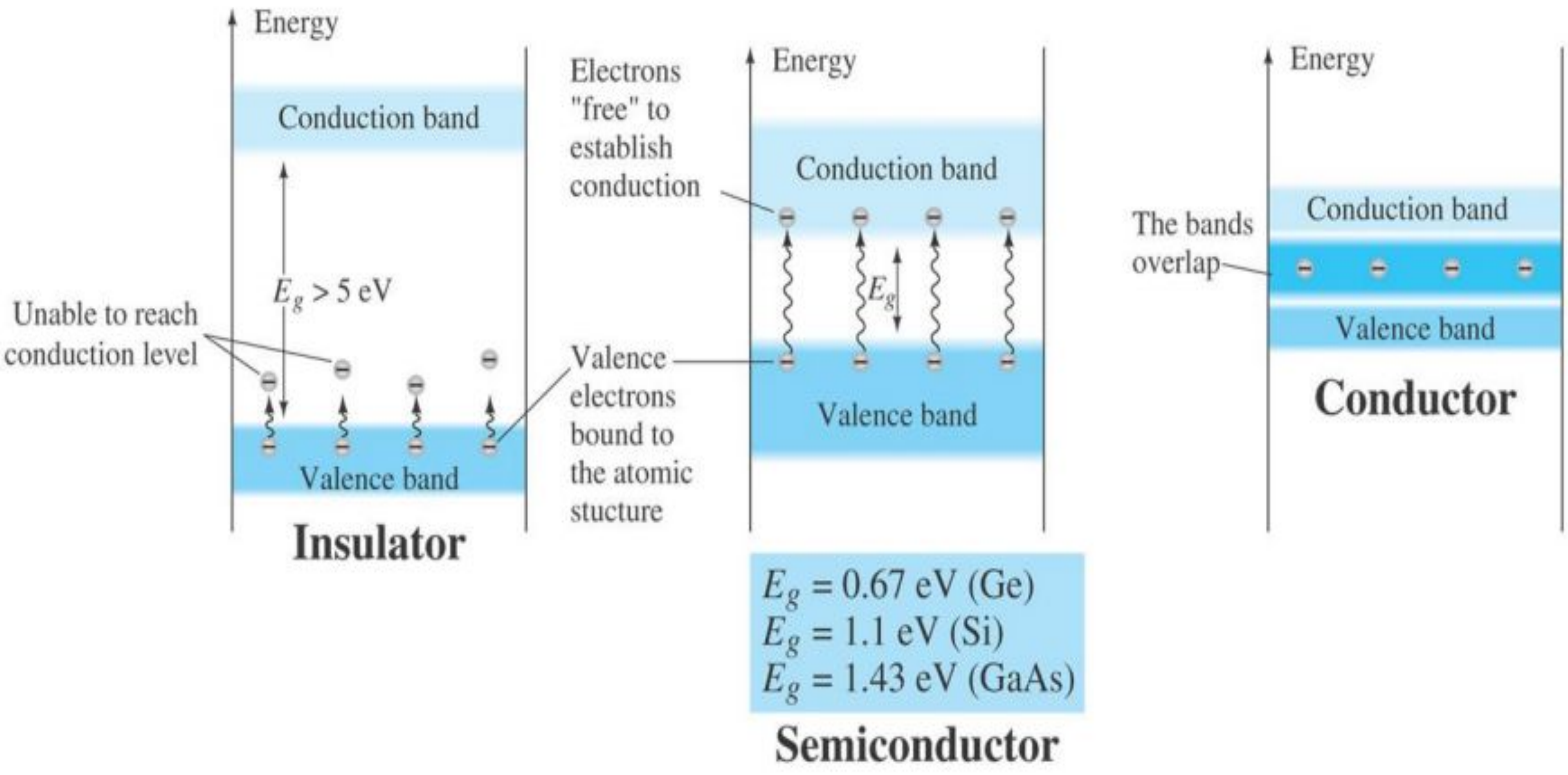
NOTE: When flow of carriers is due to externally applied voltage, resultant current is called **drift current**. When current flow is as a result of gradient of carrier concentration, it is called **diffusion current**.

Increasing conductivity by temperature

As temperature increases, the number of free electrons and holes created increases exponentially.

Therefore the conductivity of a semiconductor is influenced by temperature, This is because the application of heat makes it possible for some electrons in the valence band to move to the conduction band. **Semiconductors have negative temperature coefficient.**

Energy Gap

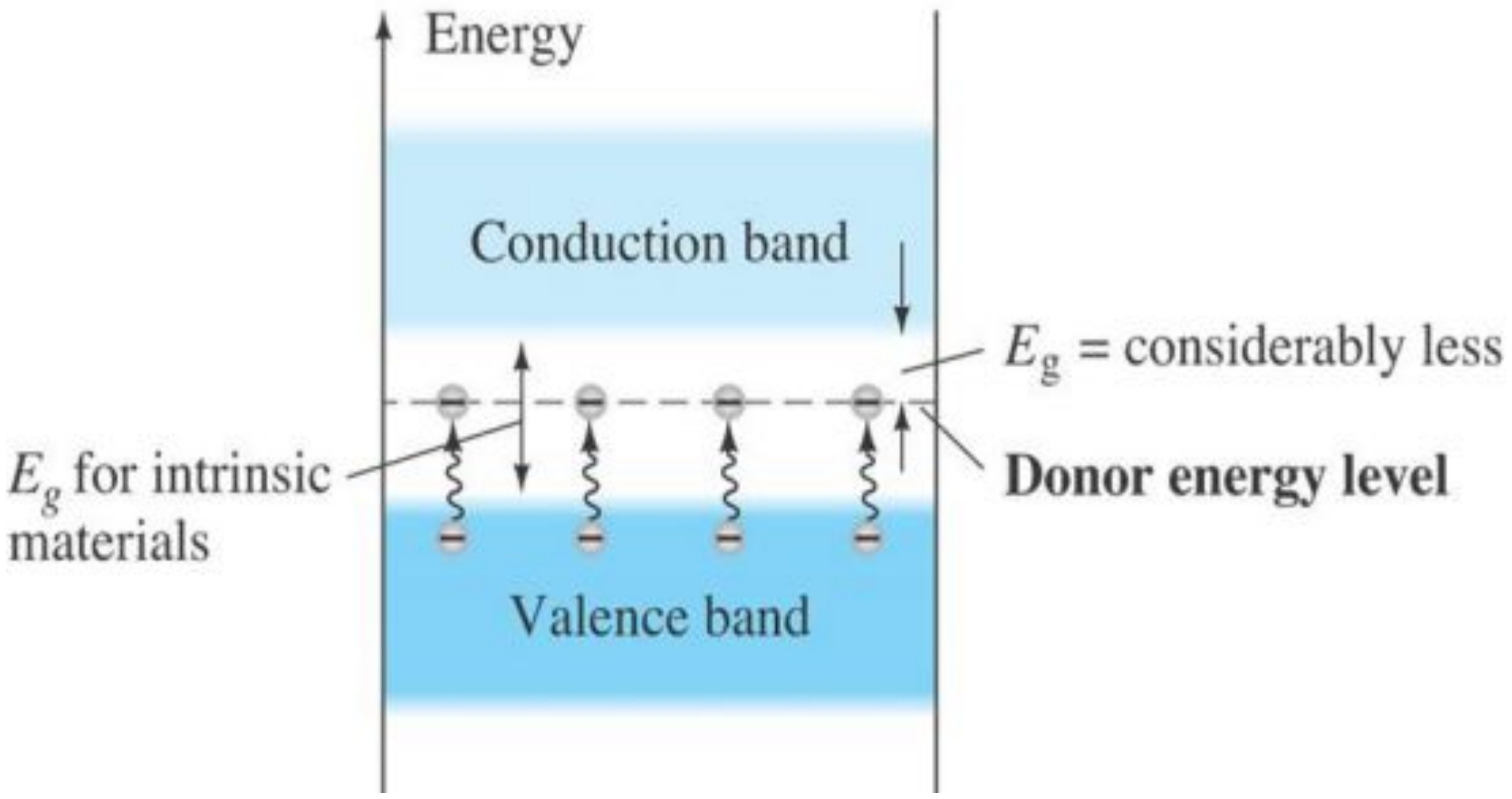


Energy
Conduction band
Unable to reach
conduction level
$E_g > 5$ eV
Valence band
Insulator
Electrons
"free" to
establish
conduction
Valence
electrons
bound to
the atomic
stucture
Energy
Conduction band
E_g
Valence band
$E_g = 0.67$ eV (Ge)
$E_g = 1.1$ eV (Si)
$E_g = 1.43$ eV (GaAs)
Semiconductor
Energy
The bands
overlap
Conduction band
Valence band
Conductor

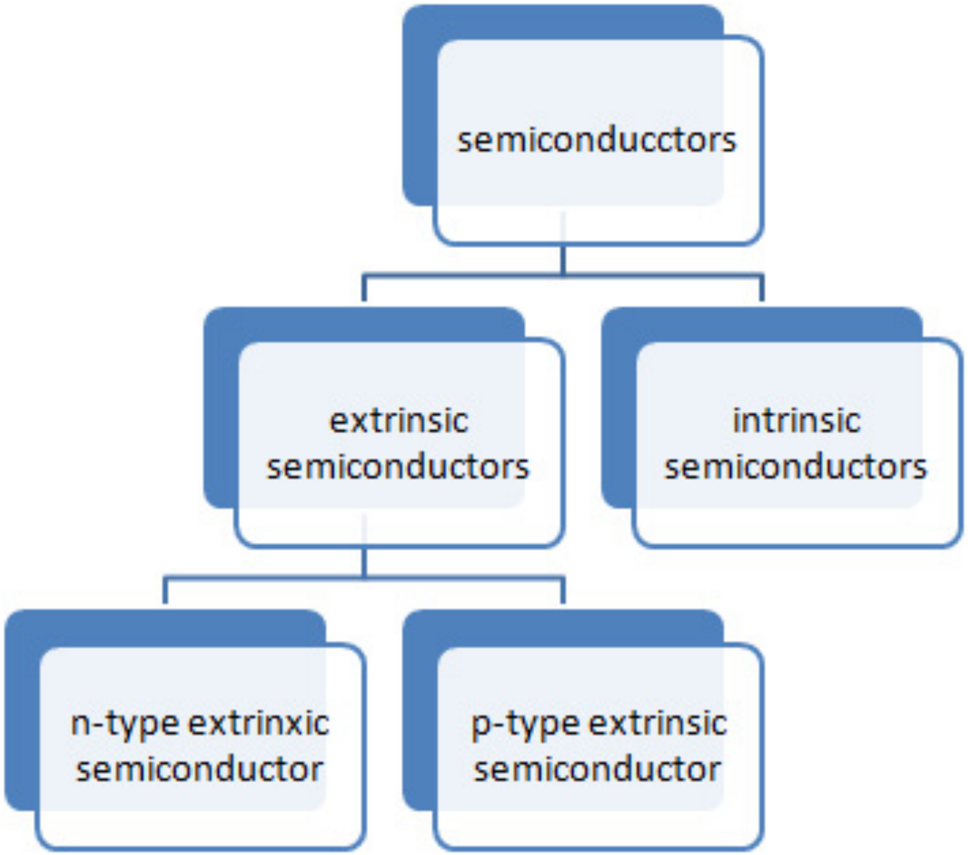
Increasing conductivity by doping

- Another way to increase the number of charge carriers is to add them in from an external source.
- **Doping** or implant is the term given to a process whereby one element is injected with atoms of another element in order to change its properties.
- Semiconductors (Si or Ge) are typically doped with elements such as Boron, Arsenic and Phosphorous to change and enhance their electrical properties.

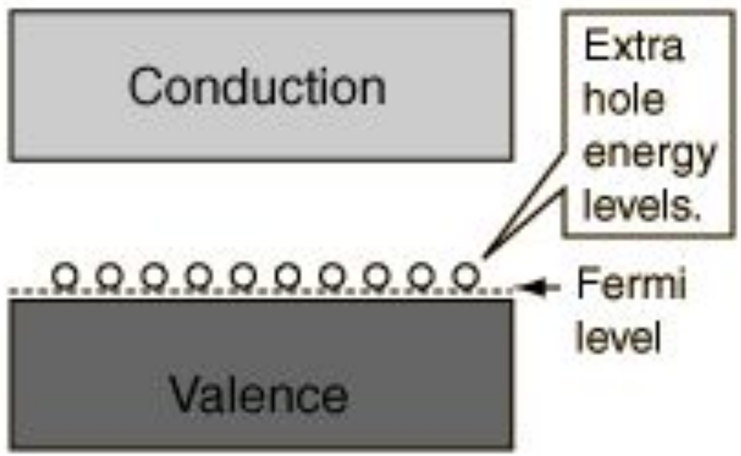
Effect of donor impurity on energy band structure



Types of Semiconductors



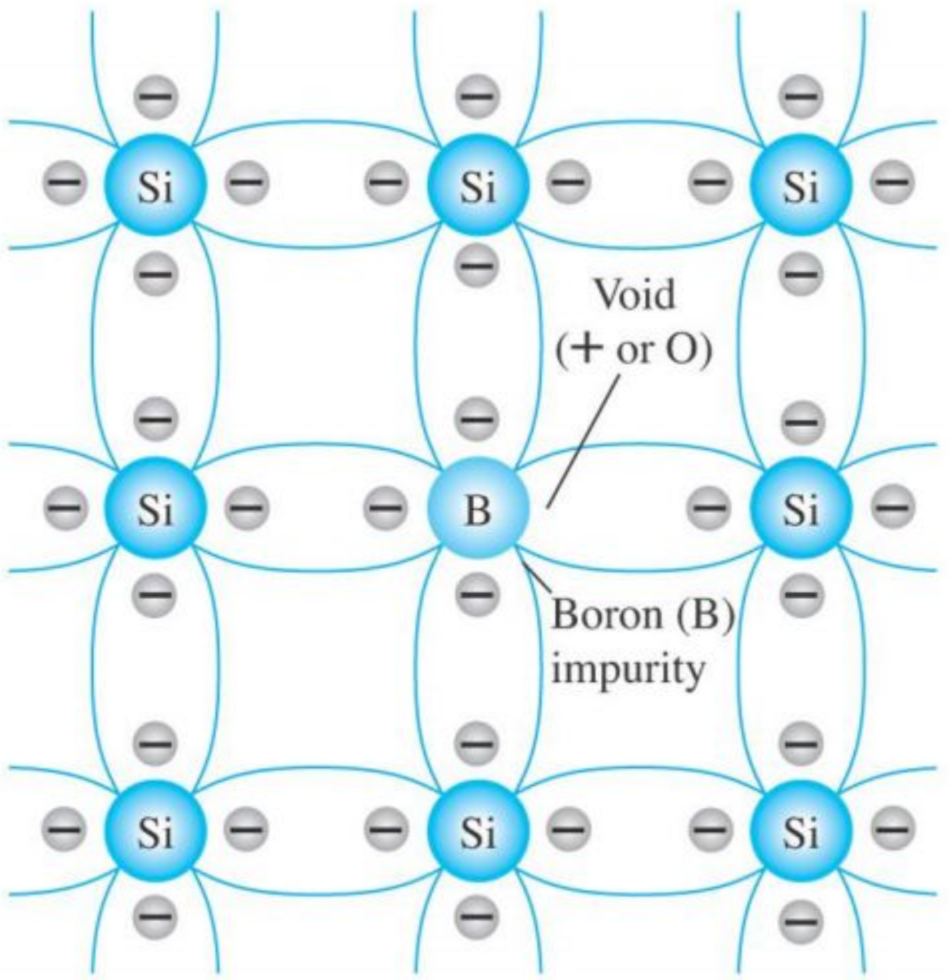
P-Type



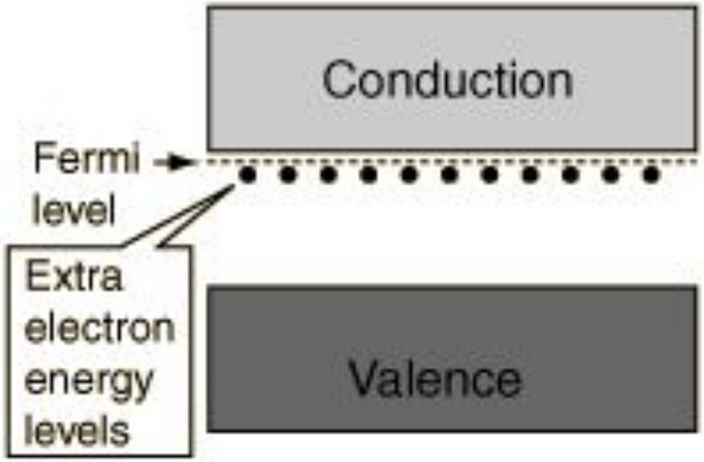
The absence of an electron creates the effect of a positive charge, hence the name P-type.

Holes can conduct current. A hole happily accepts an electron from a neighbor, moving the hole over a space. P-type silicon is a good conductor.

P type (trivalent impurity boron accepting electron from silicon)



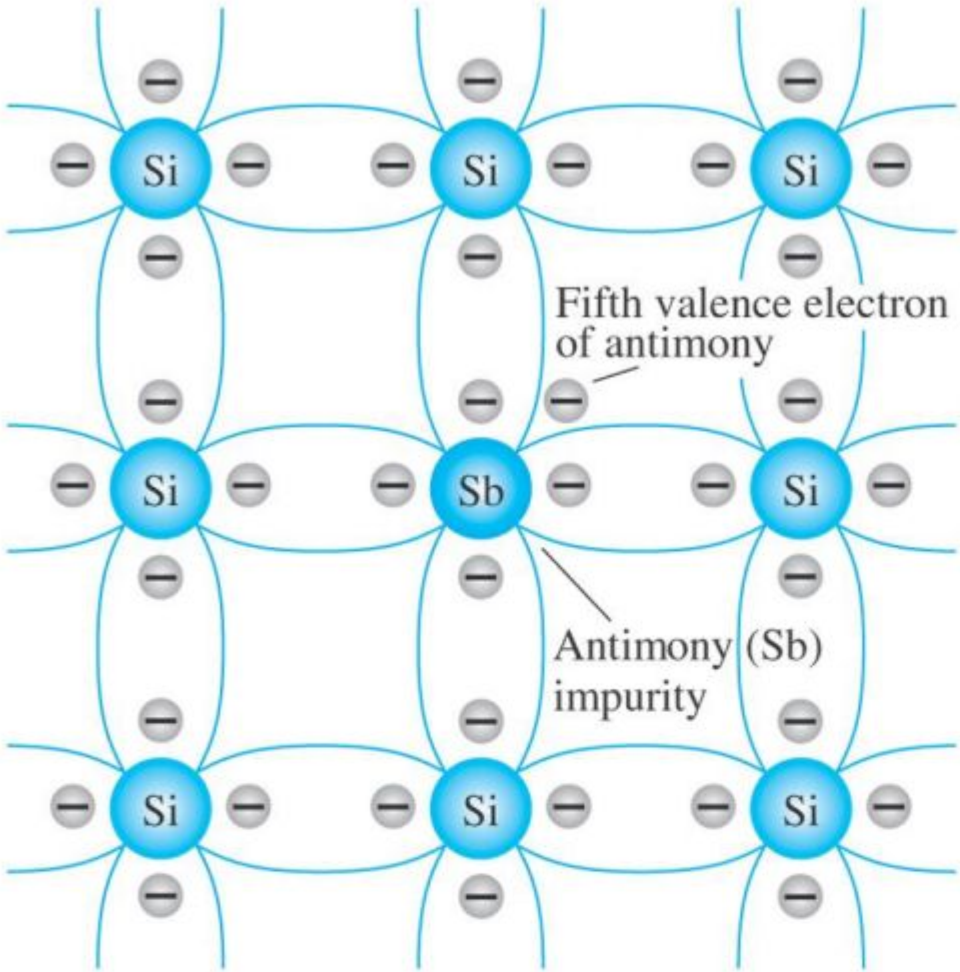
N-Type



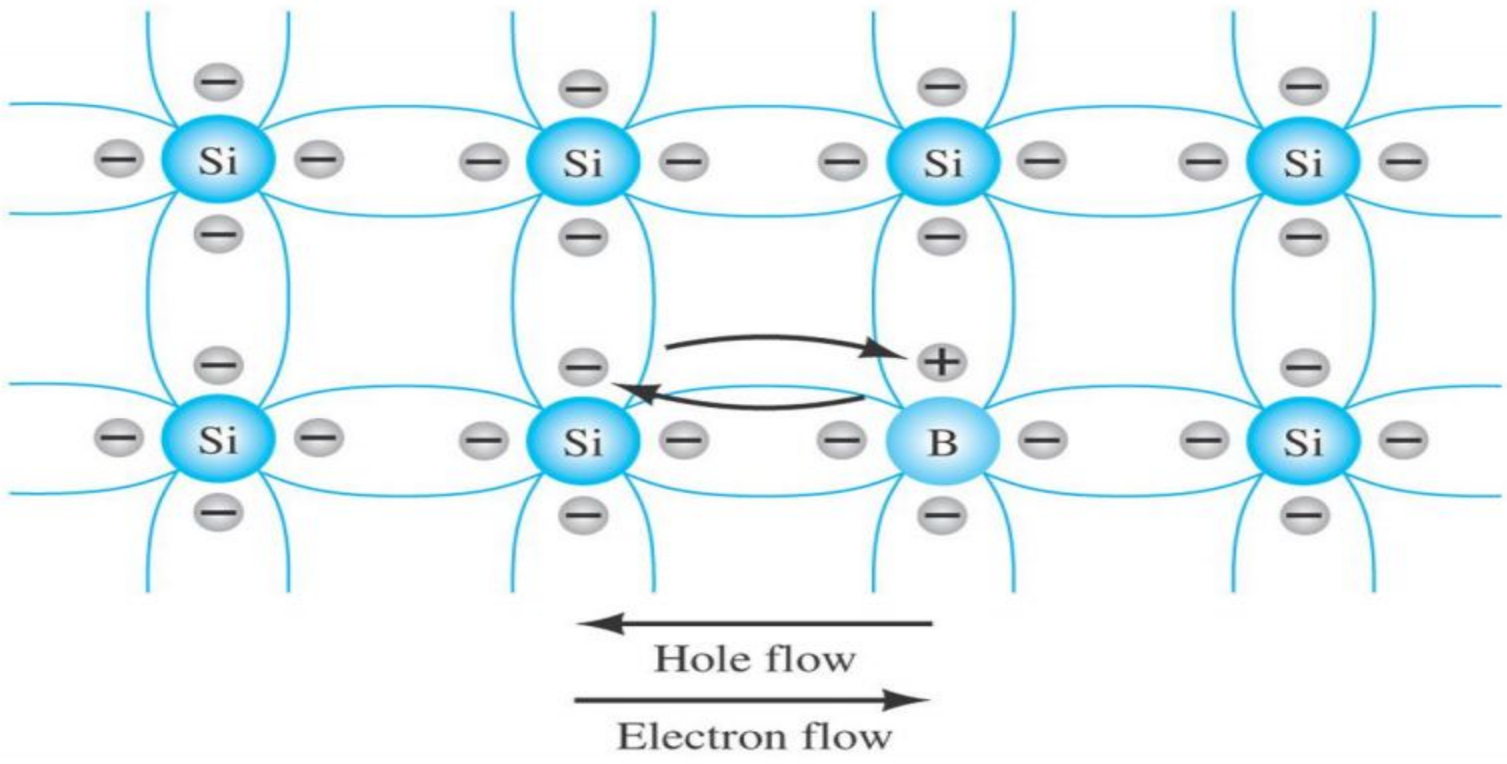
It takes only a very small quantity of the impurity to create enough free electrons to allow an electric current to flow through the silicon. N-type silicon is a good conductor.

Electrons have a negative charge, hence the name N-type.

N type (pentavalent impurity Antimony donating electron to silicon)

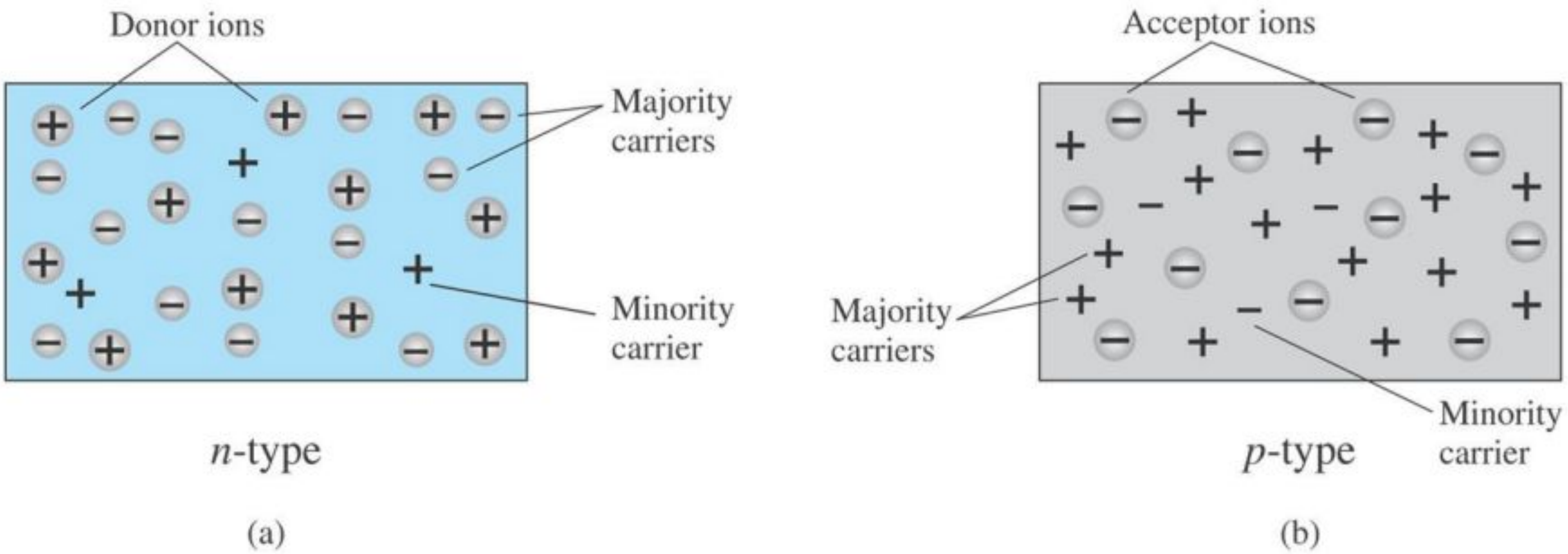


Electron versus hole flow



Valence electron (indicated by -) acquires sufficient kinetic energy to break covalent bond and fill void created by hole (indicated by +)

Majority and minority carriers



Formation of PN Junction

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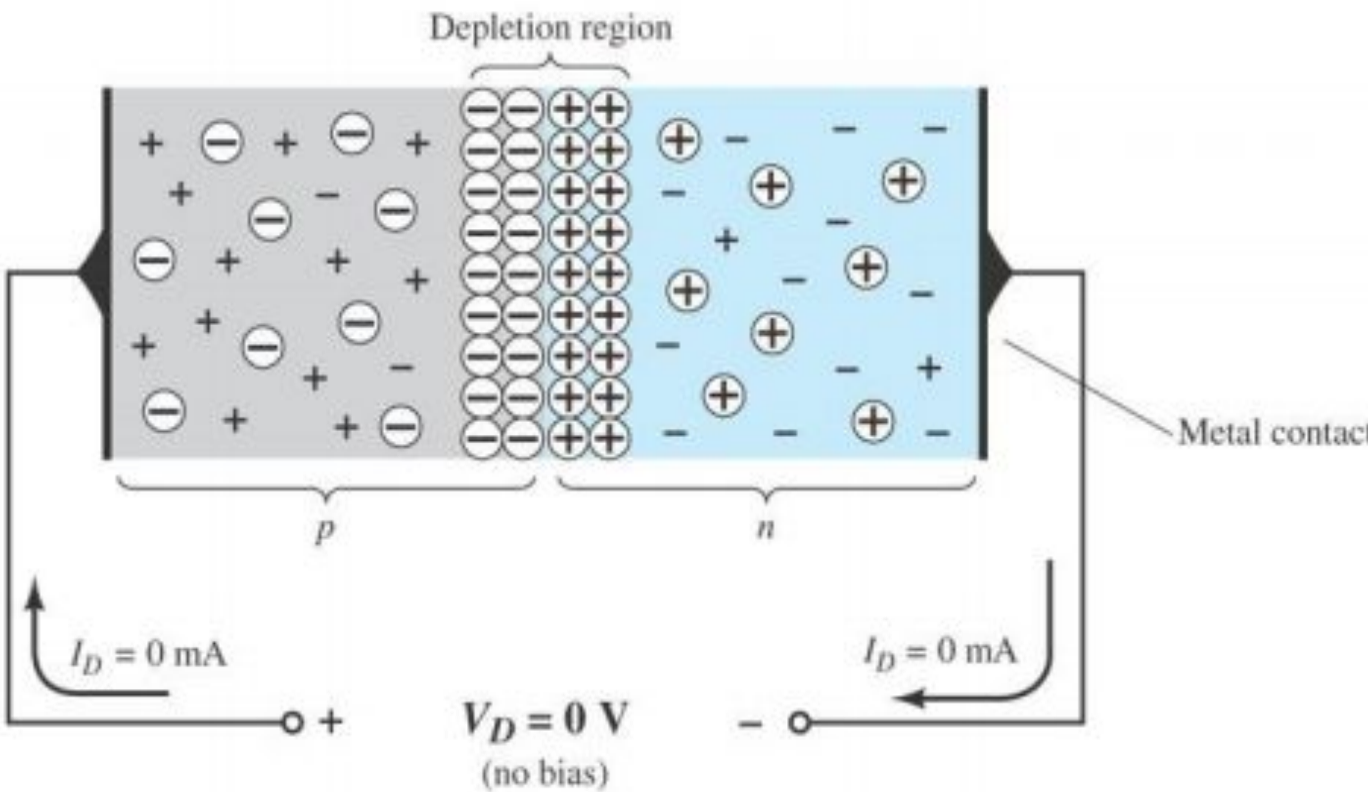
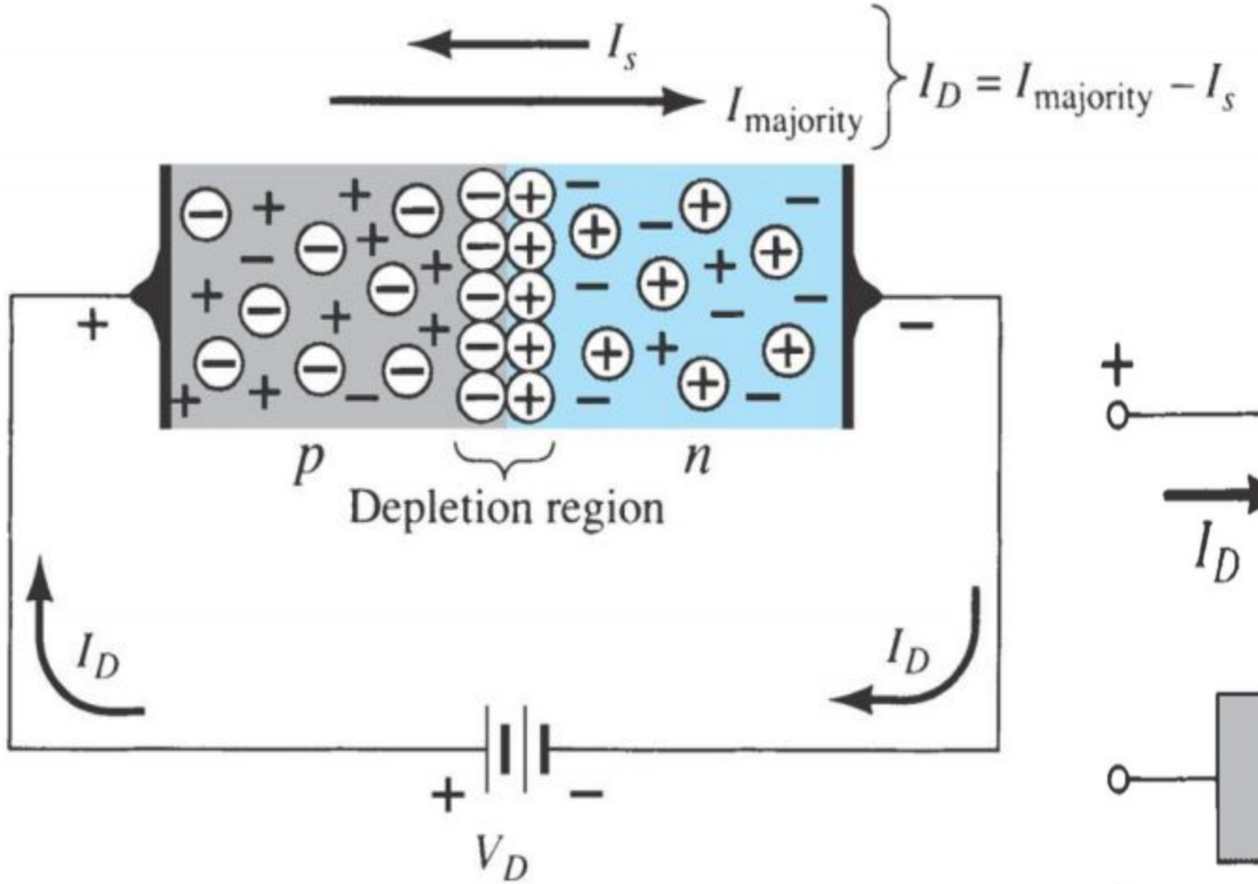
- If the n type and p type materials are joined together.
- In the n-type region there are extra electrons and in the p-type region, there are holes from the acceptor impurities .
- the electrons from the n-region which have reached the conduction band are free to diffuse across the junction and combine with holes.
- Filling a hole makes a negative ion and leaves behind a positive ion on the n-side. A space charge builds up, creating a depletion region.

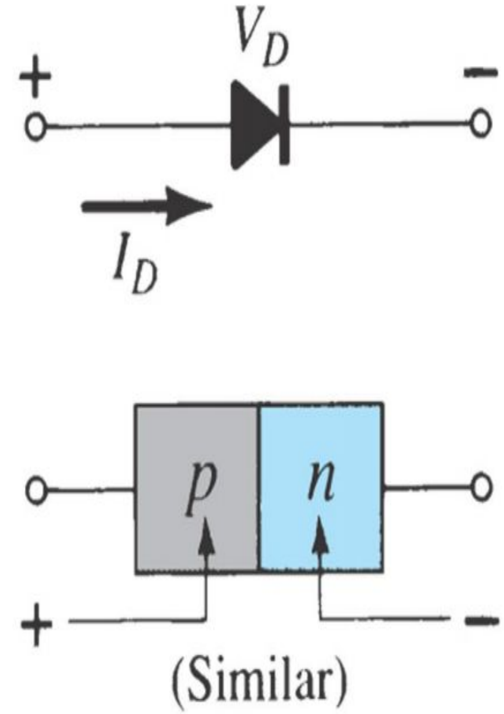
P-N Junction with no bias



- When external voltage is zero, circuit is open and the potential barrier does not allow the current to flow. Therefore, the circuit current is zero.

P-N Junction with Forward bias

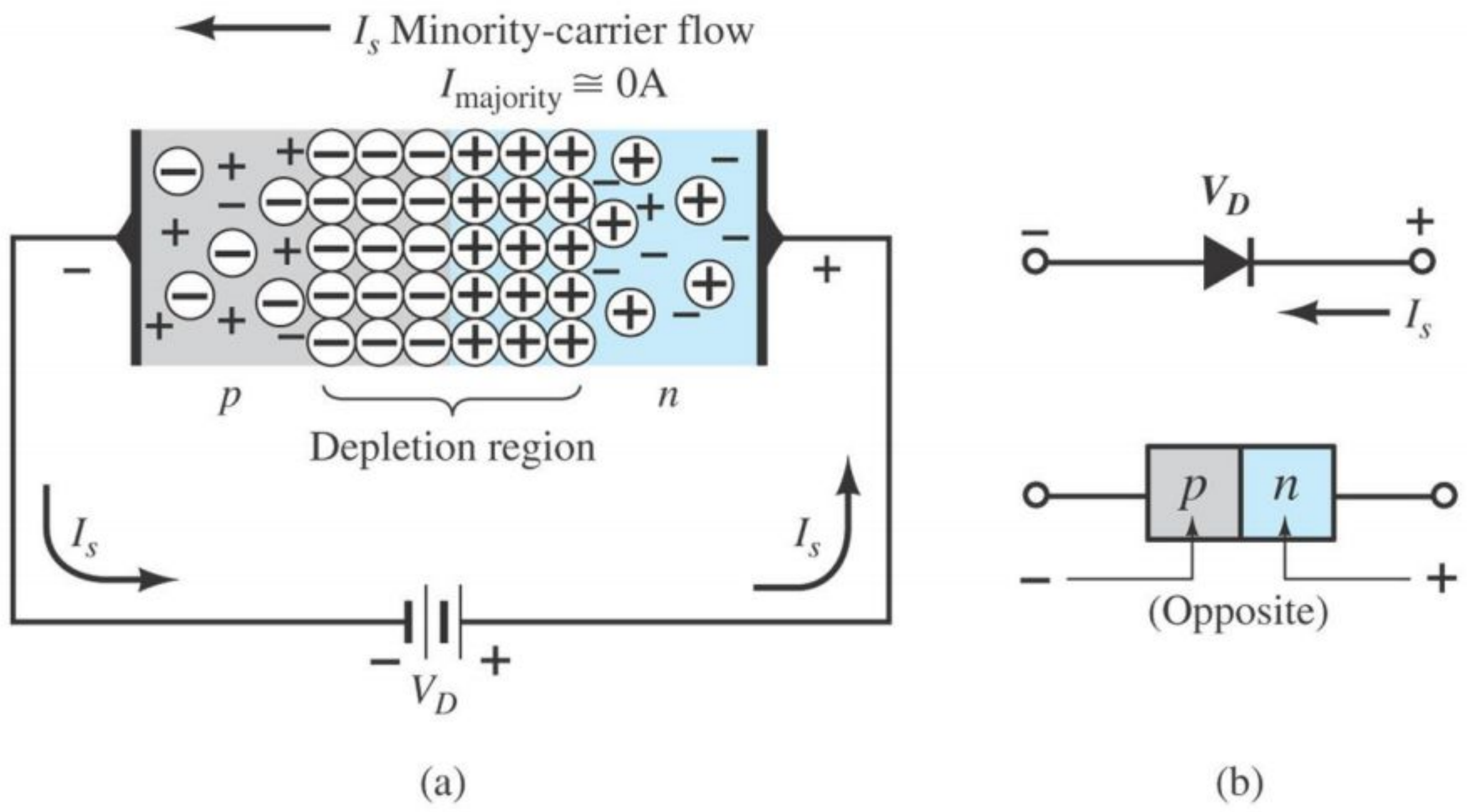




P-N Junction with Forward bias

- When P-type (Anode is connected to +ve terminal and n- type (cathode) is connected to –ve terminal of the supply voltage, is known as forward bias.
- **The potential barrier is reduced when diode is in the forward biased condition.**
- At some forward voltage, the potential barrier altogether eliminated and current starts flowing through the diode and also in the circuit. The diode is said to be in **ON state**.
- The current increases with increasing forward voltage.

P-N Junction with Reverse bias



P-N Junction with Reverse bias

- When N-type (cathode) is connected to +ve terminal and P-type (Anode) is connected to the –ve terminal of the supply voltage is known as reverse bias and the potential barrier across the junction increases.
- Therefore, the junction resistance becomes very high and a very small current (reverse saturation current) flows in the circuit. The diode is said to be in **OFF** state.
- The reverse bias current is due to minority charge carriers.

Important Definitions

- **Knee Voltage**

The voltage is applied then the junction starts increasing rapidly. It is known as knee voltage and an alternate name of this is **cut in** voltage.

- **Breakdown Voltage**

The minimum reverse voltage that makes the diode conduct appreciably in reverse.

- **Peak Inverse Voltage**

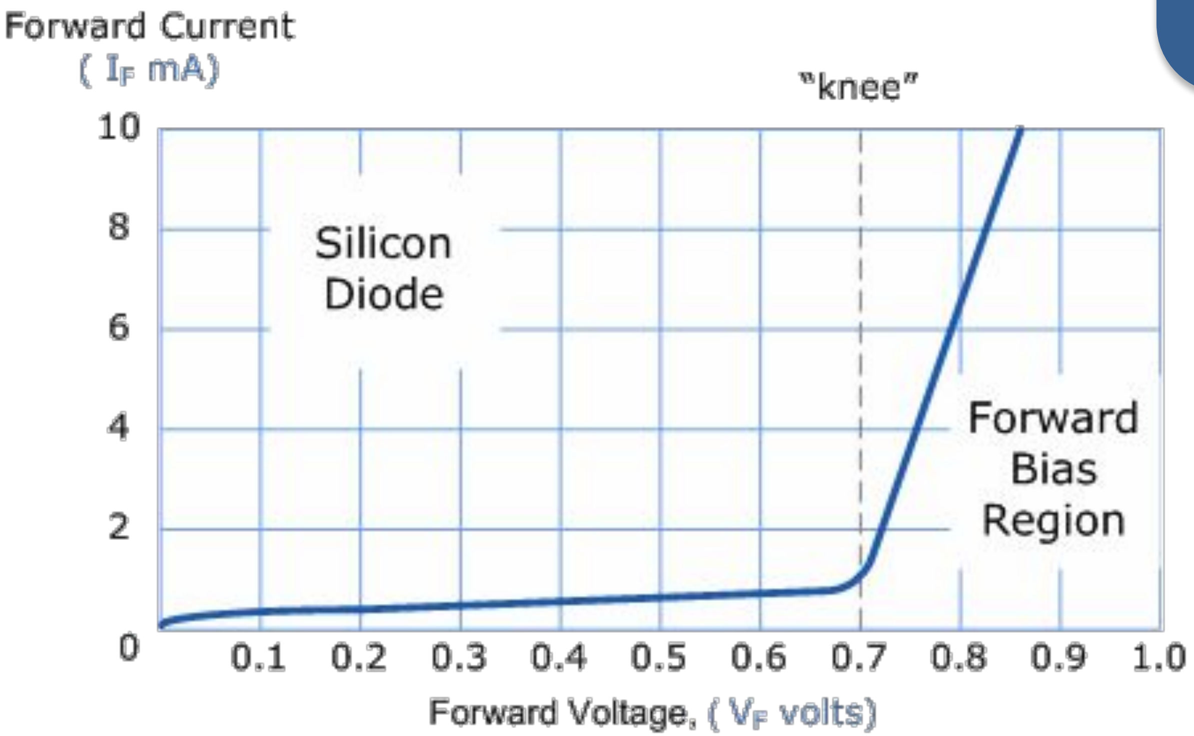
The maximum voltage a diode or other device can withstand in the reverse-biased direction before breakdown.

- **Maximum Power Rating**

Maximum power that a PN junction or diode can dissipate without damaging the device itself.

V-I Characteristics

1. **Forward Bias Characteristics**
2. **Reverse Bias Characteristics**

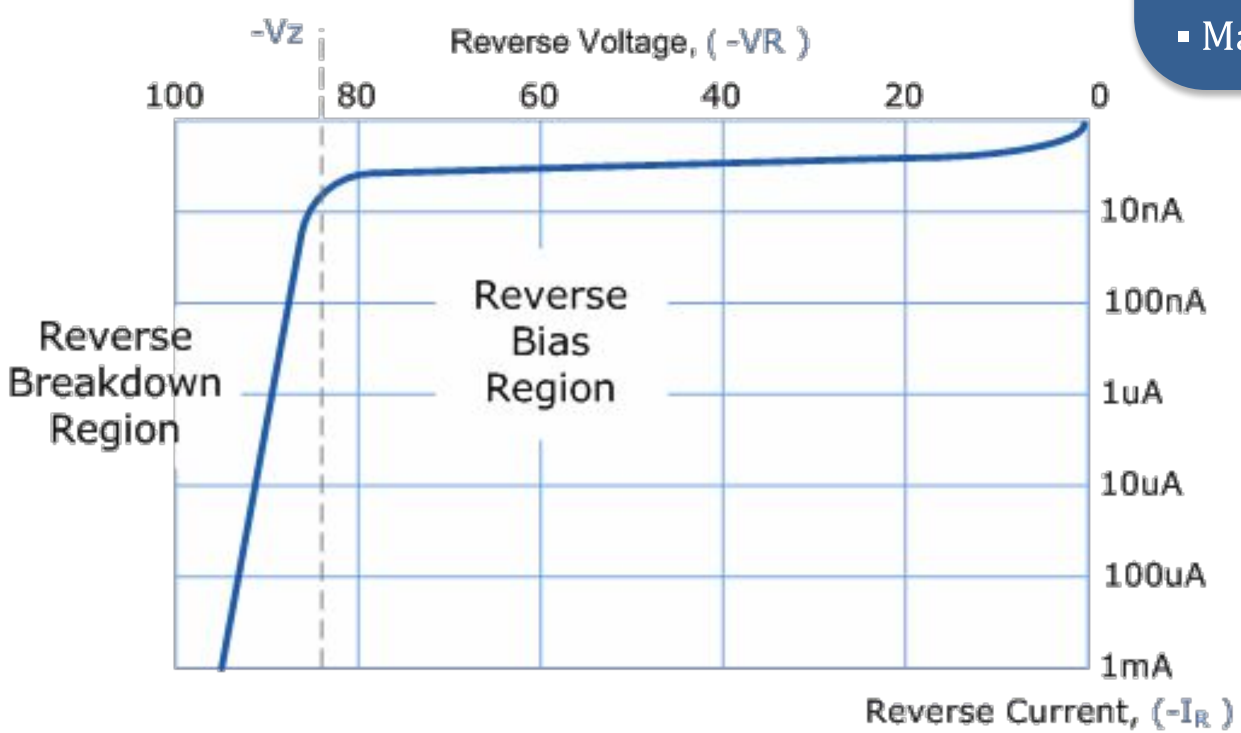


Jargons

- Knee Voltage
- Breakdown Voltage
- Maximum Forward Current
- Peak Inverse Voltage
- Maximum Power Rating

V-I Characteristics

1. **Forward Bias Characteristics**
2. **Reverse Bias Characteristics**



Jargons

- Knee Voltage
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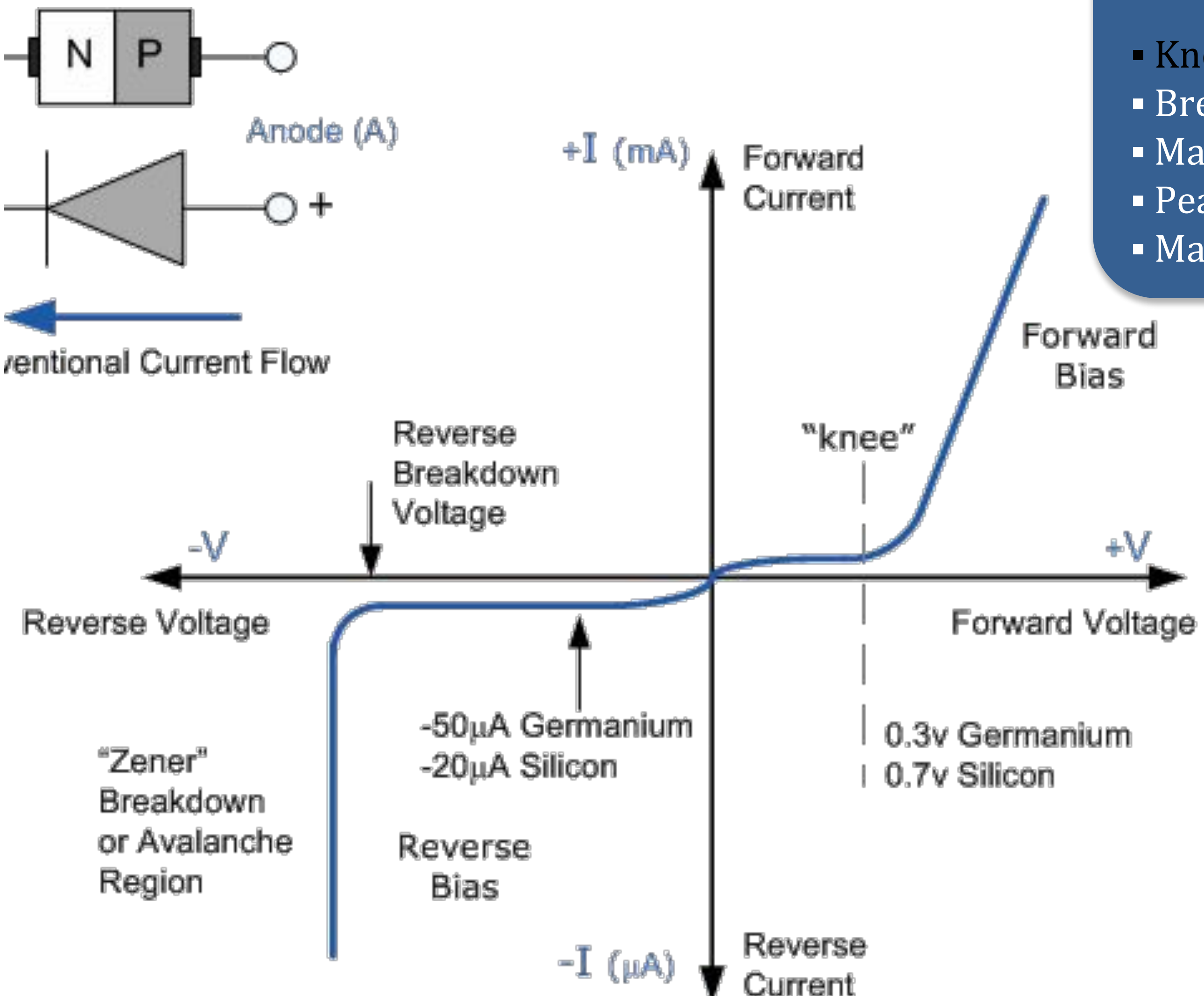
V-I Characteristics



Jargons

- Knee Voltage
- Breakdown Voltage
- Maximum Forward Current
- Peak Inverse Voltage
- Maximum Power Rating

Equivalent Circuits

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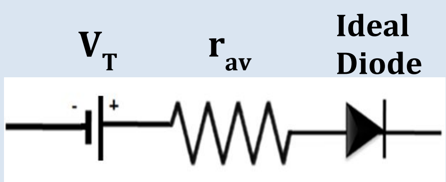
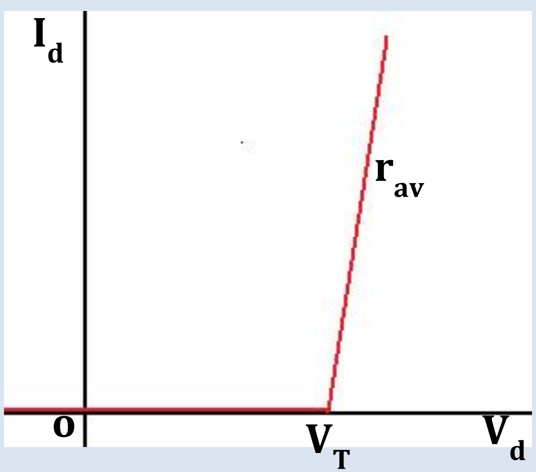
TYPE: PIECEWISE-LINEAR MODEL

CONDITION:

MODEL:



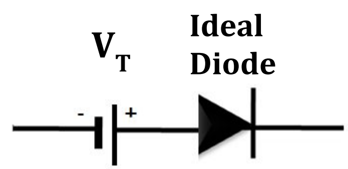
CHARACTERISTICS:



TYPE: SIMPLIFIED MODEL

CONDITION: $R_{network} \gg R_{av}$

MODEL:



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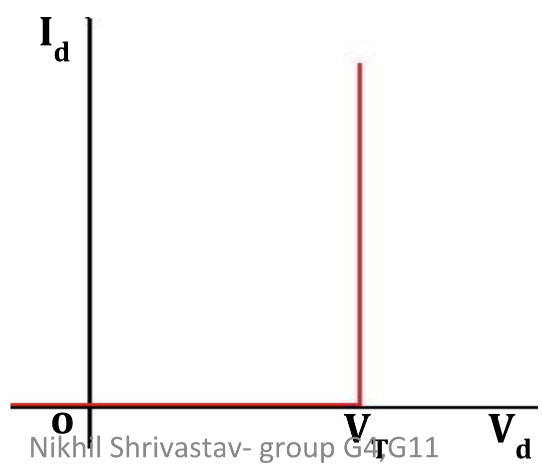
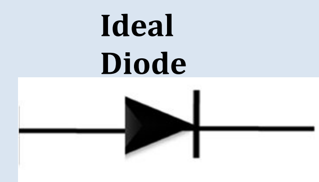


TYPE: IDEAL DIODE

CONDITION: $R_{network} \gg R_{av}$, $E_{network} \gg V_T$

MODEL:



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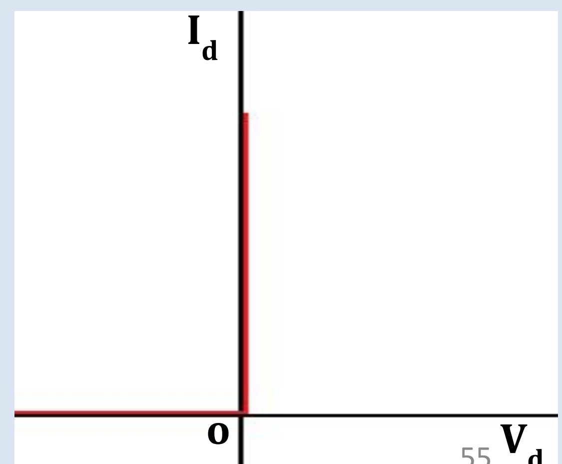

Thank you