ESSENTIALS OF PHYSICS

ELECTRONICS

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Allied: II – I Chem-A   ESSENTIALS OF PHYSICS (1 hr)   Course Code   : 20UPH2AC3

Electronics : Semiconductors-Types of Semiconductors – P-N Junction Diode and Zener diode - V-I Characteristics of PN Junction and Zener diodes- Conversion between Binary, Decimal and Hexadecimal number systems - AND, OR, NOT gates using discrete components– De-Morgan's theorems – NAND and NOR as universal gates

Text Books:

T.B.2 R.Murugeshan, Electricity and Magnetism –S.Chand & company, Seventh Revised Edition 2008

T.B 3 R.Murugeshan and Kiruthiga Sivaprasath, Modern Physics, S.Chand & Co, Sixteenth edition, New Delhi, 2012.

Introduction:

- Electronics comprises the physics, engineering, technology and applications that deal with the emission, flow and control of electrons in vacuum and matter. It uses active devices to control electron flow by amplification and rectification, which distinguishes it from classical electrical engineering which uses passive effects such as resistance, capacitance and inductance to control current flow.

- Electronics has had a major effect on the development of modern society. The identification of the electron in 1897, along with the subsequent invention of the vacuum tube which could amplify and rectify small electrical signals, inaugurated the field of electronics and the electron age.

- This distinction started around 1906 with the invention by Lee De Forest of the triode, which made electrical amplification of weak radio signals and audio signals possible with a non-mechanical device. Until 1950, this field was called "radio technology" because its principal application was the design and theory of radio transmitters, receivers, and vacuum tubes.

- The term "solid-state electronics" emerged after the first working transistor was invented by William Shockley, Walter Houser Brattain and John Bardeen at Bell Labs in 1947. The MOSFET (MOS transistor) was later invented by Mohamed Atalla and Dawon Kahng at Bell Labs in 1959.

- The MOSFET has since become the basic element in most modern electronic equipment, and is the most widely used electronic device in the world.

- Electronics is widely used in information processing, telecommunication, and signal processing. The ability of electronic devices to act as switches makes digital information-processing possible. Interconnection technologies such as circuit boards, electronics packaging technology, and other varied forms of communication infrastructure complete circuit functionality and transform the mixed electronic components into a regular working system, called an electronic system; examples are computers or control systems

- As of 2019 most electronic devices use semiconductor components to perform electron control. Commonly, electronic devices contain circuitry consisting of active semiconductors supplemented with passive elements; such a circuit is described as an electronic circuit.

- Electronics deals with electrical circuits that involve active electrical components such as vacuum tubes, transistors, diodes, integrated circuits, optoelectronics, and sensors, associated passive electrical components, and interconnection technologies. The nonlinear behaviour of active components and their ability to control electron flows makes amplification of weak signals possible.

- The study of semiconductor devices and related technology is considered a branch of solid-state physics, whereas the design and construction of electronic circuits to solve practical problems come under electronics engineering

Semiconductors:

- Semiconductors are the materials which have a conductivity between conductors (generally metals) and non-conductors or insulators (such ceramics). Semiconductors can be compounds such as gallium arsenide or pure elements, such as germanium or silicon.

Examples :

- Gallium arsenide, germanium, and silicon are some of the most commonly used semiconductors.

- Silicon is used in electronic circuit fabrication, and gallium arsenide is used in solar cells, laser diodes, etc.

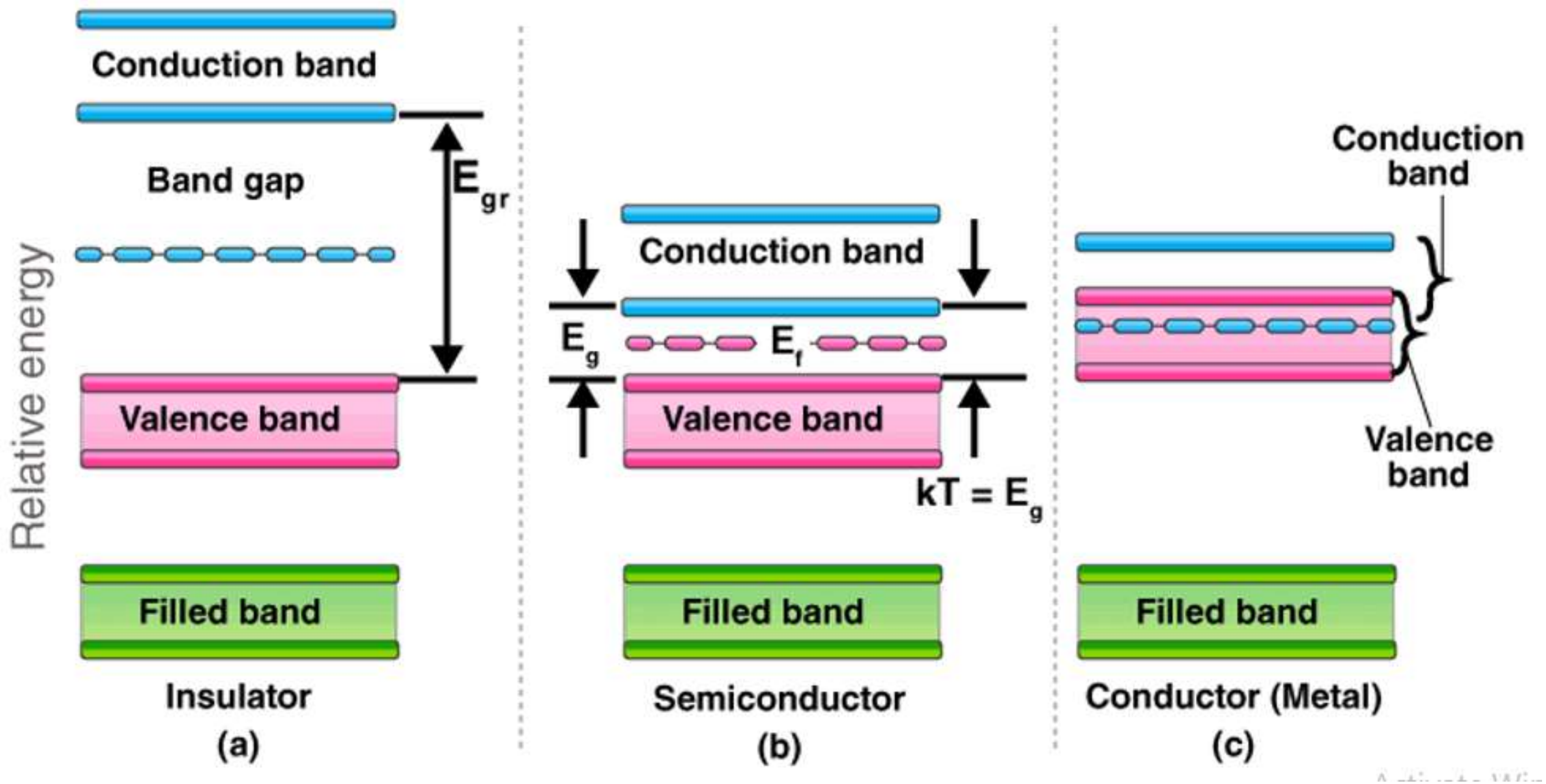
Properties of Semiconductors :

- Semiconductors can conduct electricity under preferable conditions or circumstances. This unique property makes it an excellent material to conduct electricity in a controlled manner as required.

- Unlike conductors, the charge carriers in semiconductors arise only because of external energy (thermal agitation). It causes a certain number of valence electrons to cross the energy gap and jump into the conduction band, leaving an equal amount of unoccupied energy states, i.e. holes. Conduction due to electrons and holes are equally important.

  - **Resistivity : 10^{-5} to 10^{6} Ωm**
  - **Conductivity : 10^{5} to 10^{-6} mho/m**
  - **Temperature coefficient of resistance : Negative**
  - **Current Flow : Due to electrons and holes**

ENERGY BAND GAPS IN MATERIALS



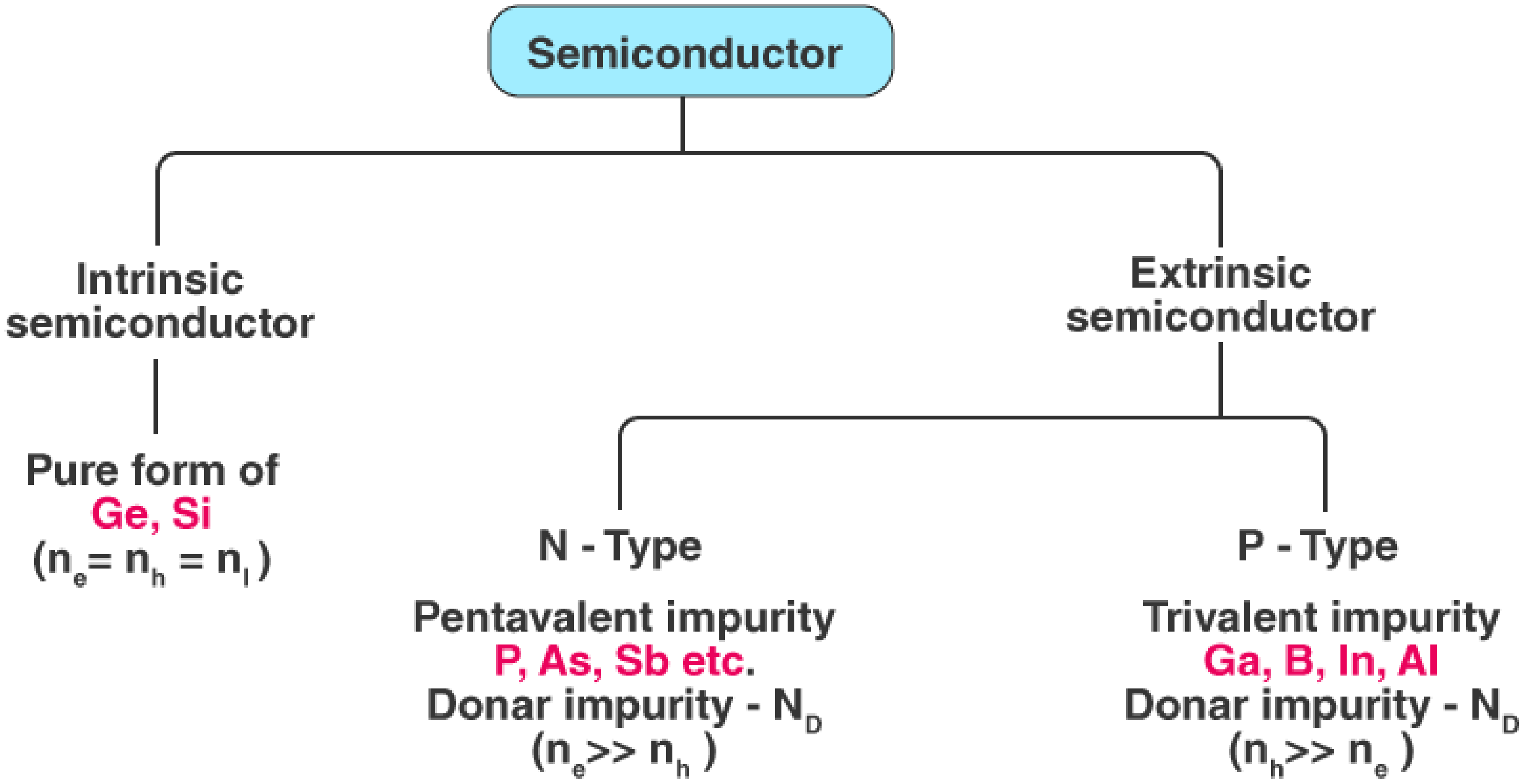
Holes and Electrons in Semiconductors:

- **Holes** and **electrons** are the types of charge carriers accountable for the flow of current in semiconductors.
- Holes (valence electrons) are the positively charged electric charge carrier whereas electrons are the negatively charged particles.
- Both electrons and holes are equal in magnitude but opposite in polarity.

Types of Semiconductors:

Semiconductors can be classified as:

- Intrinsic Semiconductor
- Extrinsic Semiconductor


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
($n_h >> n_e$)

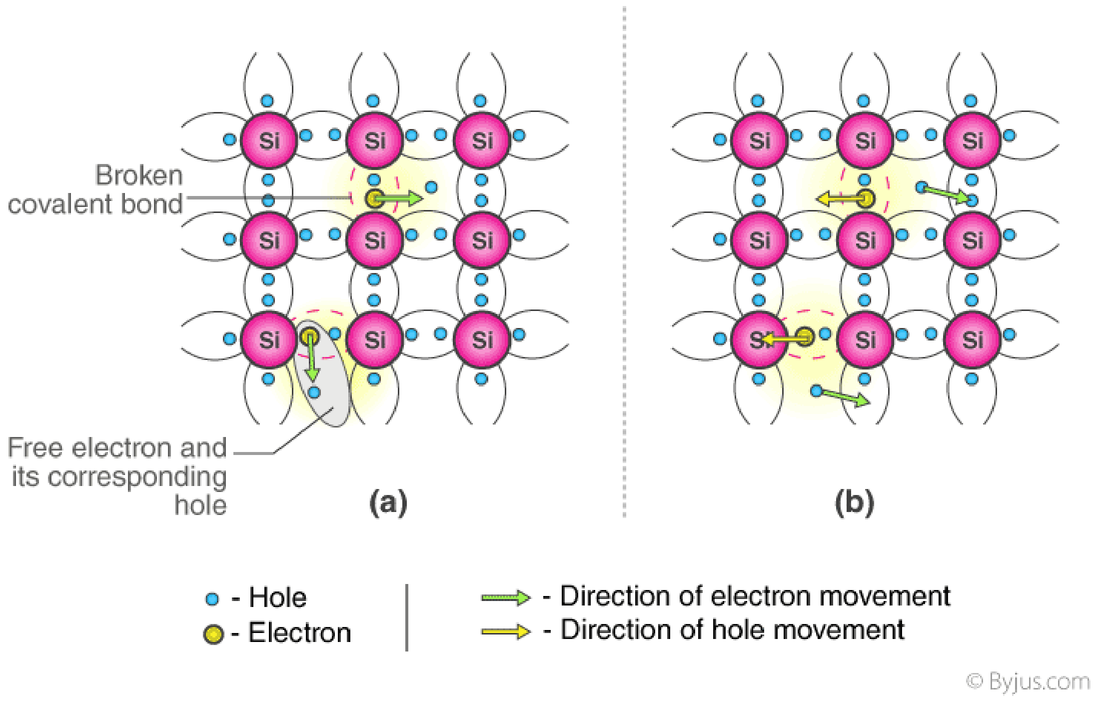
Intrinsic Semiconductor:

An intrinsic type of semiconductor material is made to be very pure chemically. It is made up of only a single type of element. It has the number of free electrons and holes are equal

- **Germanium (Ge)** and **Silicon (Si)** are the most common type of intrinsic semiconductor elements. They have four valence electrons (tetravalent). They are bound to the atom by covalent bond at absolute zero temperature.

- When the temperature rises, due to collisions, few electrons are unbounded and become free to move through the lattice, thus creating an absence in its original position (hole).

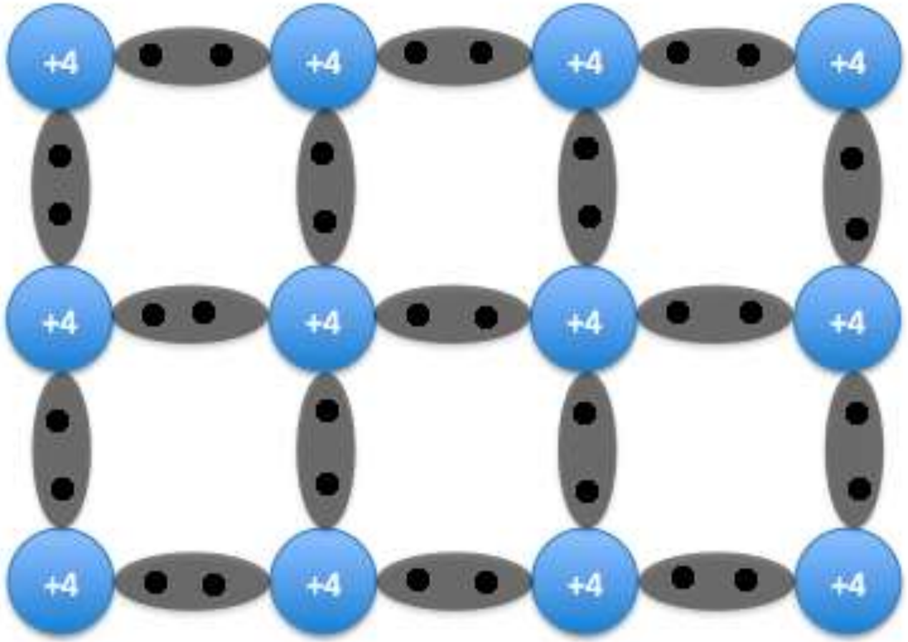
- These free electrons and holes contribute to the conduction of electricity in the semiconductor. The negative and positive charge carriers are equal in number.



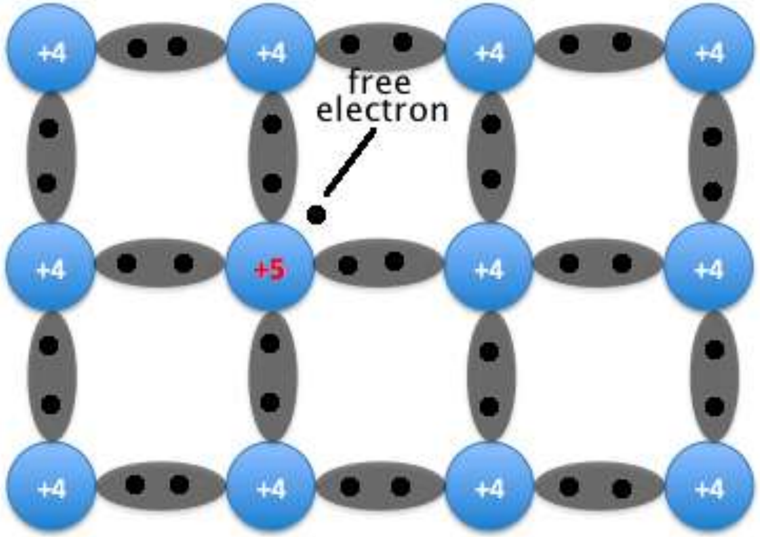
Extrinsic Semiconductor:

- The conductivity of semiconductors can be greatly improved by introducing a small number of suitable replacement atoms called **IMPURITIES**.
- The process of adding impurity atoms to the pure semiconductor is called **DOPING**. Usually, only 1 atom in 10^7 is replaced by a dopant atom in the doped semiconductor. An extrinsic semiconductor can be further classified into:

  - **N-type Semiconductor**
  - **P-type Semiconductor**



N-Type Semiconductor:



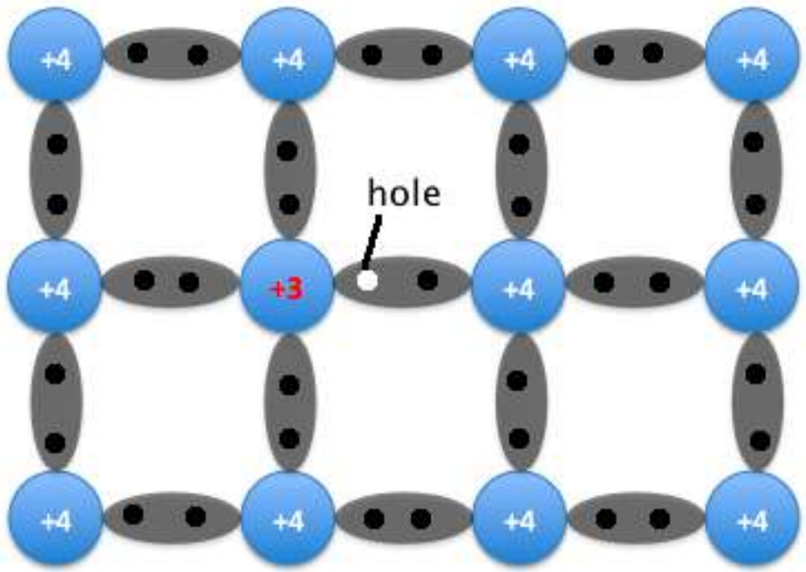
- When a pure semiconductor (Silicon or Germanium) is doped by **pentavalent impurity** (P, As, Bi) then, four electrons out of five valence electrons bonds with the four electrons of Ge or Si.

- The fifth electron of the dopant is set free. Thus the impurity atom donates a free electron for conduction in the lattice and is called “**Donar**“.

- Since the number of free electron increases by the addition of an impurity, the negative charge carriers increase. Hence it is called **n-type semiconductor**.

- Crystal as a whole is neutral, but the donor atom becomes an immobile positive ion. As conduction is due to a large number of free electrons, the electrons in the n-type semiconductor are the MAJORITY CARRIERS and holes are the MINORITY CARRIERS.

P-Type Semiconductor:



- When a pure semiconductor is doped with a **trivalent impurity** (B, Ga, In) then, the three valence electrons of the impurity bonds with three of the four valence electrons of the semiconductor.

- This leaves an absence of electron (hole) in the impurity. These impurity atoms which are ready to accept bonded electrons are called "**Acceptors**".

- With the increase in the number of impurities, holes (the positive charge carriers) are increased. Hence, it is called **p-type semiconductor**.

- Crystal as a whole is neutral, but the acceptors become an immobile negative ion. As conduction is due to a large number of holes, the holes in the p-type semiconductor are MAJORITY CARRIERS and electrons are MINORITY CARRIERS.

Uses of Semiconductors in Everyday life:

- Temperature sensors are made with semiconductor devices.
- They are used in 3D printing machines
- Used in microchips and self-driving cars
- Used in calculators, solar plates, computers and other electronic devices.
- Transistor and MOSFET used as a switch in Electrical Circuits are manufactured using the semiconductors.

Industrial Uses of Semiconductors:

- The physical and chemical properties of semiconductors make them capable of designing technological wonders like microchips, transistors, LEDs, solar cells, etc.
- The microprocessor used for controlling the operation of space vehicles, trains, robots, etc is made up of transistors and other controlling devices which are manufactured by semiconductor materials.

P-N junction semiconductor diode

What is p-n junction semiconductor diode?

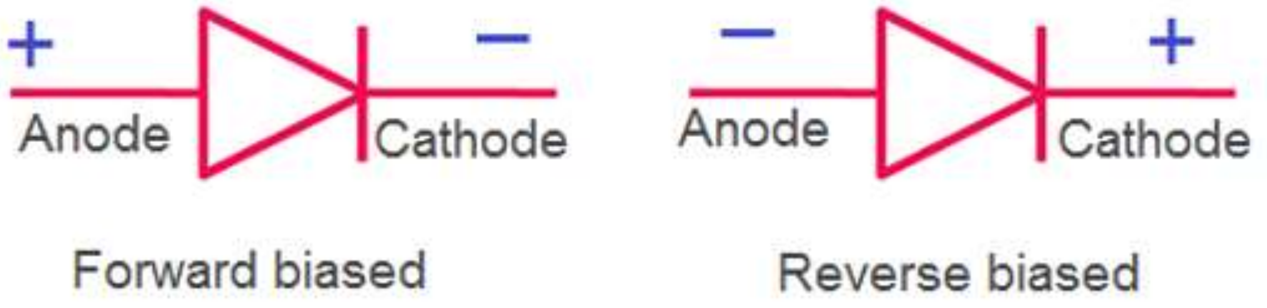
- A p-n junction diode is two-terminal or two-electrode semiconductor device, which allows the electric current in only one direction while blocks the electric current in opposite or reverse direction.

- If the diode is forward biased, it allows the electric current flow. On the other hand, if the diode is reverse biased, it blocks the electric current flow. P-N junction semiconductor diode is also called as p-n junction semiconductor device

- In n-type semiconductors, free electrons are the majority charge carriers whereas in p-type semiconductors, holes are the majority charge carriers.

- When the n-type semiconductor is joined with the p-type semiconductor, a p-n junction is formed. The p-n junction, which is formed when the p-type and n-type semiconductors are joined, is called as p-n junction diode.

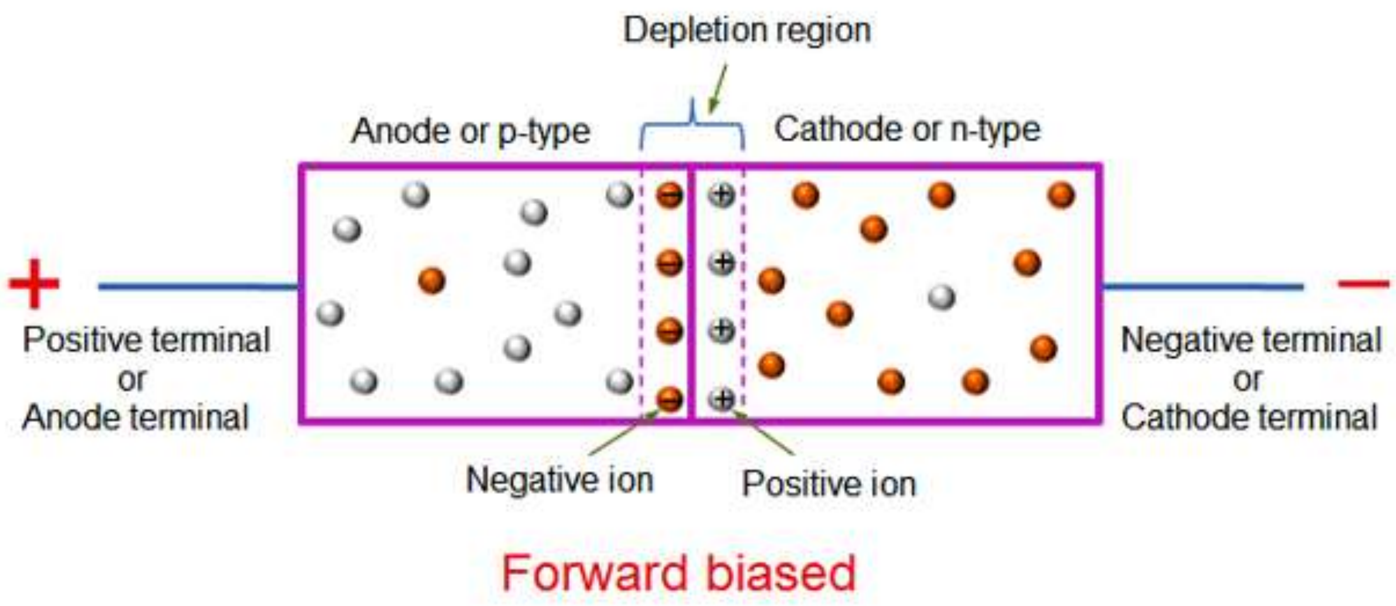
The basic symbol of p-n junction diode under forward bias and reverse bias is shown in the below figure



- In the above figure, arrowhead of a diode indicates the conventional direction of electric current when the diode is forward biased (from positive terminal to the negative terminal).

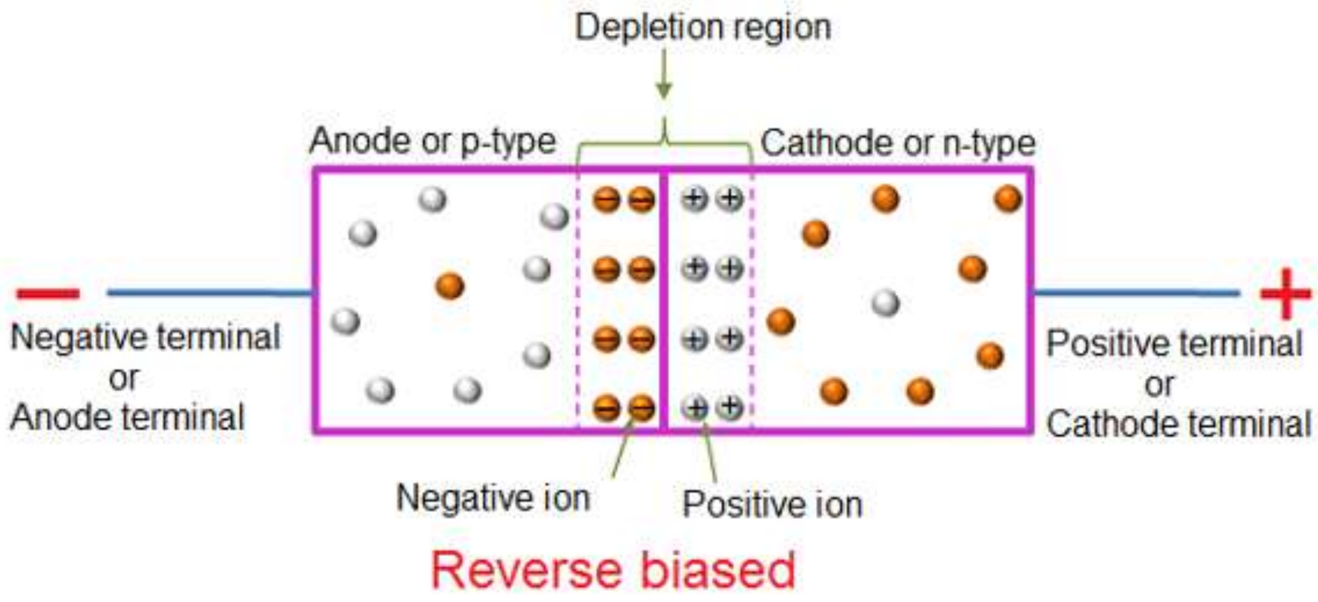
- The holes which moves from positive terminal (anode) to the negative terminal (cathode) is the conventional direction of current.

- The free electrons moving from negative terminal (cathode) to the positive terminal (anode) actually carry the electric current. However, due to the convention we have to assume that the current direction is from positive terminal to the negative terminal.



- In forward biased p-n junction diode (p-type connected to positive terminal and n-type connected to negative terminal), anode terminal is a positive terminal whereas cathode terminal is negative terminal.

- The free electrons are attracted towards the anode terminal or positive terminal whereas the holes are attracted towards the cathode terminal or negative terminal.



- If the diode is reverse biased (p-type connected to negative terminal and n-type connected to positive terminal), the anode terminal becomes a negative terminal whereas the cathode terminal becomes a positive terminal.

- The holes in the p-type semiconductor get attracted towards the negative terminal. The free electrons from the negative terminal cannot move towards the positive terminal because the wide depletion region at the p-n junction resists or opposes the flow of free electrons.

Zener diode

What is zener diode?

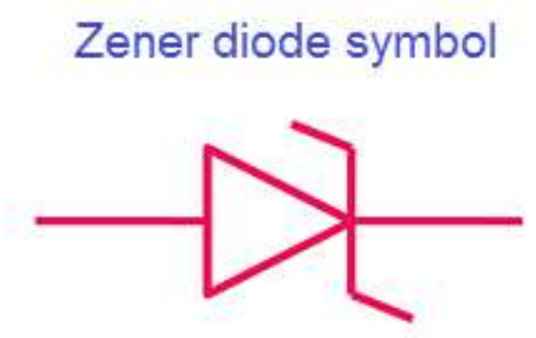
- A zener diode is a special type of device designed to operate in the zener reverse breakdown region

- Zener diodes acts like normal p-n junction diodes under forward biased condition. When forward biased voltage is applied to the zener diode it allows large amount of electric current and blocks only a small amount of electric current

- Zener diode is heavily doped than the normal p-n junction diode. Hence, it has very thin depletion region. Therefore, zener diodes allow more electric current than the normal p-n junction diodes.

Symbol of zener diode

- Zener diode consists of two terminals: cathode and anode.

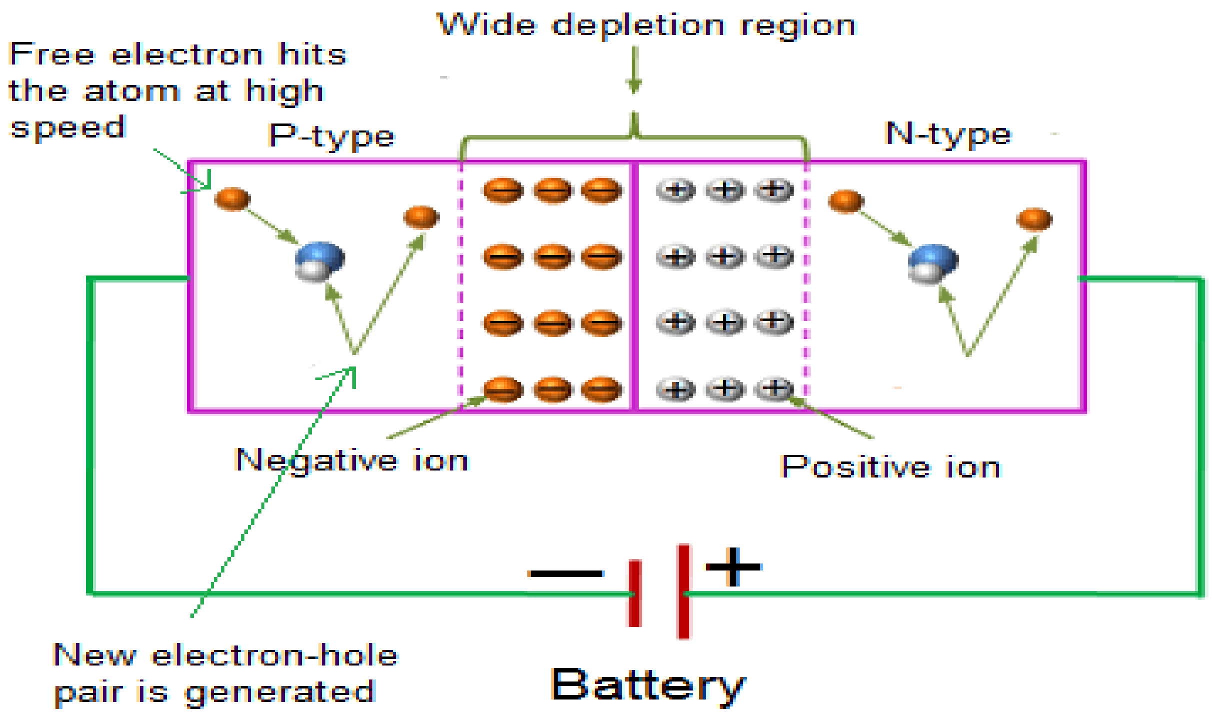


Breakdown in zener diode

There are two types of reverse breakdown regions in a zener diode: **Avalanche breakdown** and **Zener breakdown**.

Avalanche breakdown

- The avalanche breakdown occurs in both normal diodes and zener diodes at high reverse voltage.
- When high reverse voltage is applied to the p-n junction diode, the free electrons (minority carriers) gains large amount of energy and accelerated to greater velocities.



- The free electrons moving at high speed will collides with the atoms and knock off more electrons

- These electrons are again accelerated and collide with other atoms. Because of this continuous collision with the atoms, a large number of free electrons are generated

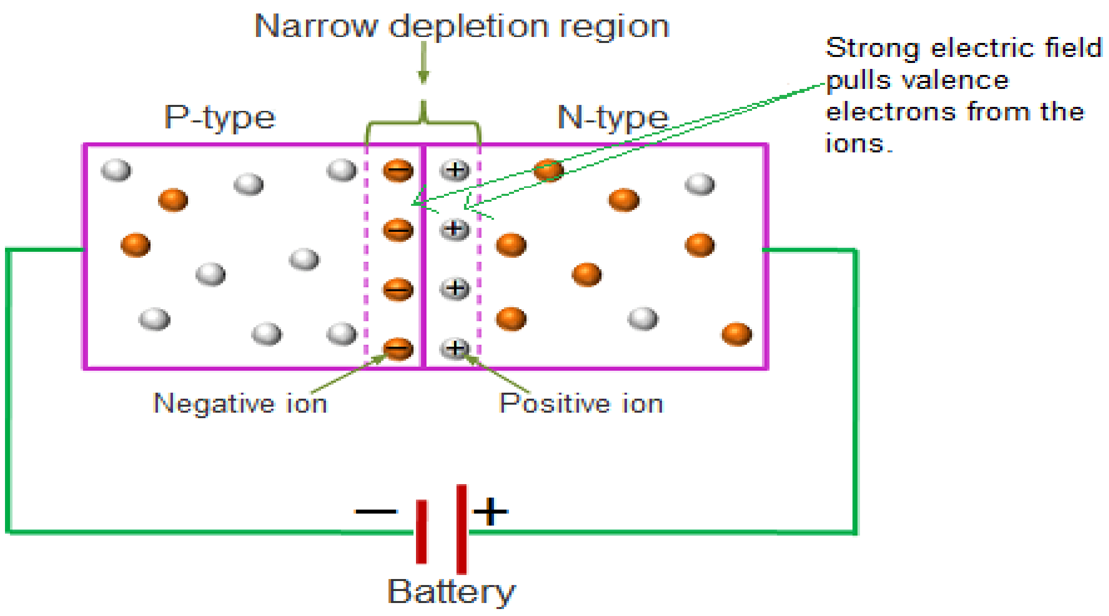
- As a result, electric current in the diode increases rapidly. This sudden increase in electric current may permanently destroys the normal diode

- However, avalanche diodes may not be destroyed because they are carefully designed to operate in avalanche breakdown region. Avalanche breakdown occurs in zener diodes with zener voltage (Vz) greater than 6V

Zener breakdown

- The zener breakdown occurs in heavily doped p-n junction diodes because of their narrow depletion region.

- When reverse biased voltage applied to the diode is increased, the narrow depletion region generates strong electric field.



- When reverse biased voltage applied to the diode reaches close to zener voltage, the electric field in the depletion region is strong enough to pull electrons from their valence band.

- The valence electrons which gains sufficient energy from the strong electric field of depletion region will breaks bonding with the parent atom

- The valance electrons which break bonding with parent atom will become free electrons. This free electrons carry electric current from one place to another place.

- At zener breakdown region, a small increase in voltage will rapidly increases the electric current.

Static V-I Characteristics of PN Junction Diode

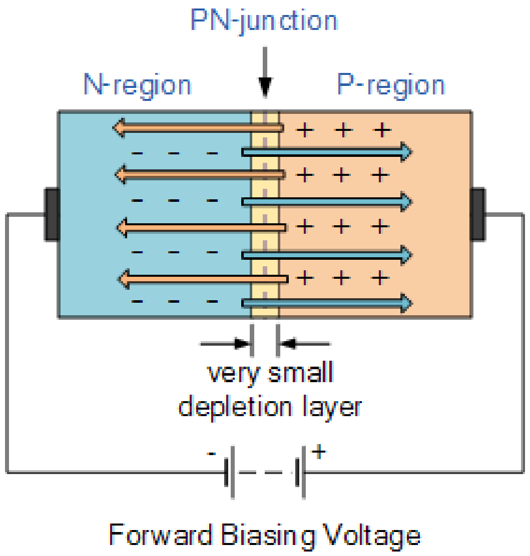
There are two operating regions and three possible “biasing” conditions for the standard Junction Diode and these are:

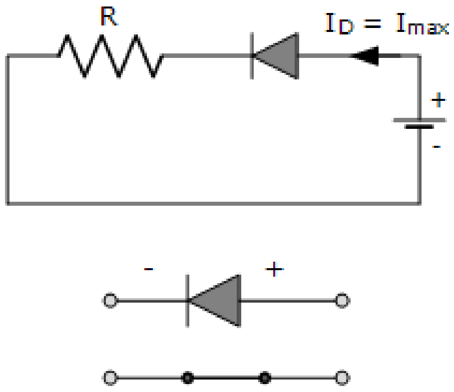
1. **Zero Bias** – No external voltage potential is applied to the PN junction diode.

2. **Forward Bias** – The voltage potential is connected positive, (+ve) to the P-type material and negative, (-ve) to the N-type material across the diode which has the effect of Decreasing the PN junction diodes width.

3. **Reverse Bias** – The voltage potential is connected negative, (-ve) to the P-type material and positive, (+ve) to the N-type material across the diode which has the effect of Increasing the PN junction diode’s width.

Forward Biased PN Junction Diode





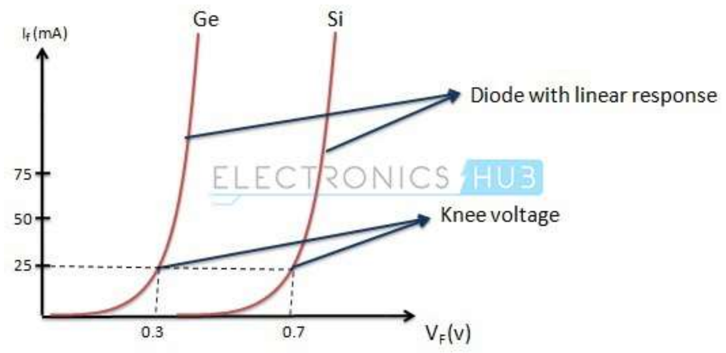
- When a diode is connected in a Forward Bias condition, a negative voltage is applied to the N-type material and a positive voltage is applied to the P-type material

- If this external voltage becomes greater than the value of the potential barrier, approx. 0.7 volts for silicon and 0.3 volts for germanium, the potential barriers opposition will be overcome and current will start to flow.

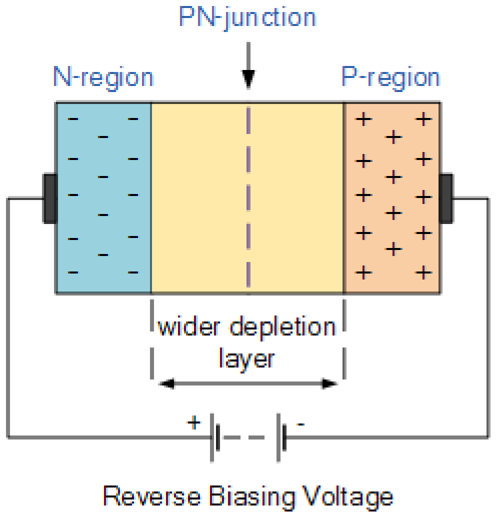
- This is because the negative voltage pushes or repels electrons towards the junction giving them the energy to cross over and combine with the holes being pushed in the opposite direction towards the junction by the positive voltage

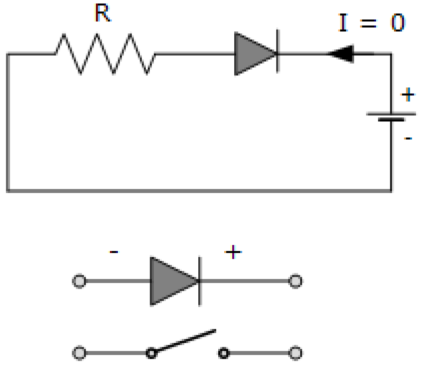
- This results in a characteristics curve of zero current flowing up to this voltage point, called the “knee” on the static curves and then a high current flow through the diode with little increase in the external voltage

- When a junction diode is Forward Biased the thickness of the depletion region reduces and the diode acts like a short circuit allowing full circuit current to flow.



Reverse Biased PN Junction Diode





- When a diode is connected in a Reverse Bias condition, a positive voltage is applied to the N-type material and a negative voltage is applied to the P-type material
- The positive voltage applied to the N-type material attracts electrons towards the positive electrode and away from the junction, while the holes in the P-type end are also attracted away from the junction towards the negative electrode
- If the external reverse voltage applied on the p-n junction diode is increased, the free electrons from the n-type semiconductor and the holes from the p-type semiconductor are moved away from the p-n junction. This increases the width of depletion region.
- The net result is that the depletion layer grows wider due to a lack of electrons and holes and presents a high impedance path, almost an insulator and a high potential barrier is created across the junction thus preventing current from flowing through the semiconductor material

VI characteristics of zener diode

- When forward biased voltage is applied to the zener diode, it works like a normal diode. However, when reverse biased voltage is applied to the zener diode, it works in different manner

- When reverse biased voltage is applied to a zener diode, it allows only a small amount of leakage current until the voltage is less than zener voltage

- When reverse biased voltage applied to the zener diode reaches zener voltage, it starts allowing large amount of electric current

- At this point, a small increase in reverse voltage will rapidly increases the electric current. Because of this sudden rise in electric current, breakdown occurs called zener breakdown

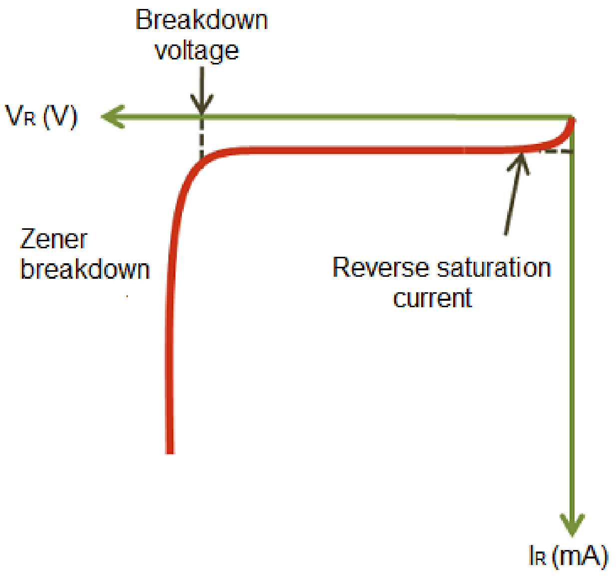


Fig: Zener breakdown

- The zener breakdown voltage of the zener diode is depends on the amount of doping applied. If the diode is heavily doped, zener breakdown occurs at low reverse voltages. On the other hand, if the diode is lightly doped, the zener breakdown occurs at high reverse voltages. Zener diodes are available with zener voltages in the range of 1.8V to 400V

Number System

- The technique to represent and work with numbers is called number system. Decimal number system is the most common number system. Other popular number systems include binary number system, octal number system, hexadecimal number system, etc.

Decimal Number System

- Decimal number system is a base 10 number system having 10 digits from 0 to 9. This means that any numerical quantity can be represented using these 10 digits. Decimal number system is also a positional value system. This means that the value of digits will depend on its position. Let us take an example to understand this.
- Say we have three numbers – 734, 971 and 207. The value of 7 in all three numbers is different−
    - In 734, value of 7 is 7 hundreds or 700 or 7×100 or 7×10^2
    - In 971, value of 7 is 7 tens or 70 or 7×10 or 7×10^1
    - In 207, value 0f 7 is 7 units or 7 or 7×1 or 7×10^0
- The weightage of each position can be represented as follows −

10^5	10^4	10^3	10^2	10^1	10^0

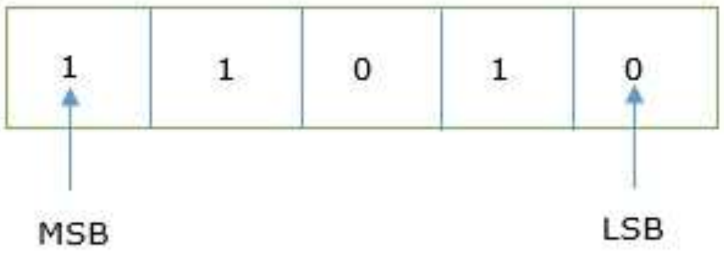
Binary Number System

- The easiest way to vary instructions through electric signals is two-state system – on and off. On is represented as 1 and off as 0, though 0 is not actually no signal but signal at a lower voltage. The number system having just these two digits – 0 and 1 – is called binary number system.

- Each binary digit is also called a bit. Binary number system is also positional value system, where each digit has a value expressed in powers of 2, as displayed here.

2^5	2^4	2^3	2^2	2^1	2^0

- In any binary number, the rightmost digit is called **least significant bit** (LSB) and leftmost digit is called **most significant bit** (MSB)



- Decimal equivalent of this number is sum of product of each digit with its positional value.

$$11010_2 = 1\times2^4 + 1\times2^3 + 0\times2^2 + 1\times2^1 + 0\times2^0$$

$$= 16 + 8 + 0 + 2 + 0$$

$$= 26_{10}$$

- Computer memory is measured in terms of how many bits it can store. Here is a chart for memory capacity conversion

1 byte (B)	= 8 bits
1 Kilobytes (KB)	= 1024 bytes
1 Megabyte (MB)	= 1024 KB
1 Gigabyte (GB)	= 1024 MB
1 Terabyte (TB)	= 1024 GB
1 Exabyte (EB)	= 1024 PB
1 Zettabyte	= 1024 EB
1 Yottabyte (YB)	= 1024 ZB

Hexadecimal Number System

- Hexa number system has 16 symbols – 0 to 9 and A to F where A is equal to 10, B is equal to 11 and so on till F. Hexadecimal number system is also a positional value system with where each digit has its value expressed in powers of 16, as shown here −

16^5	16^4	16^3	16^2	16^1	16^0

- Decimal equivalent of any hexadecimal number is sum of product of each digit with its positional value.

$$27FA_{16} = 2\times16^3 + 7\times16^2 + 15\times16^1 + 10\times16^0$$

$$= 8192 + 1792 + 240 + 10$$

$$= 10234_{10}$$

Number System Relationship

The following table depicts the relationship between decimal, binary, octal and hexadecimal number systems.

HEXADECIMAL	DECIMAL	OCTAL	BINARY
0	0	0	0000
1	1	1	0001
2	2	2	0010
3	3	3	0011
4	4	4	0100
5	5	5	0101
6	6	6	0110
7	7	7	0111
8	8	10	1000
9	9	11	1001
A	10	12	1010
B	11	13	1011
C	12	14	1100
D	13	15	1101
E	14	16	1110
F	15	17	1111

Decimal to Binary

- Decimal numbers can be converted to binary by repeated division of the number by 2 while recording the remainder. Let’s take an example to see how this happens

		Remainder	
2	43		
2	21	1	MSB
2	10	1	
2	5	0	
2	2	1	
2	1	0	
	0	1	LSB

The remainders are to be read from bottom to top to obtain the binary equivalent.

$$43_{10} = 101011_2$$

Decimal to Hexadecimal

Decimal numbers can be converted to Hexa decimal by repeated division of the number by 16 while recording the remainder. Let’s take an example to see how this happens

		Remainder
16	423	
16	26	7
16	1	A
	0	1

Reading the remainders from bottom to top we get,

$$423_{10} = 1A7_{16}$$

Binary to Hexadecimal

To convert a binary number to hexadecimal number, these steps are followed

- Starting from the least significant bit, make groups of four bits
- If there are one or two bits less in making the groups, 0s can be added after the most significant bit.
- Convert each group into its equivalent Hexa-decimal number

$\underline{1\ 0\ 1\ 1\ 0\ 1\ 1\ 0\ 1\ 0\ 1}$

$\underline{0101}$ $\underline{1011}$ $\underline{0101}$

5 B 5

Therefore, $(10110110101)_2 = (5\ B\ 5)_{16}$

Binary to Decimal Conversion

- The process of converting binary to decimal is quite simple. The process starts from multiplying the bits of binary number with its corresponding positional weights. And lastly, we add all those products.

- Let's take an example to understand how the conversion is done from binary to decimal

Example : $(10110\ .\ 001)_2$

We multiplied each bit of $(10110.001)_2$ with its respective positional weight, and last we add the products of all the bits with its weight.

$$(10110\ .\ 001)_2 = (1\times2^4) + (0\times2^3) + (1\times2^2) + (1\times2^1) + (0\times2^0)\ .\ (0\times2^{-1}) + (0\times2^{-2}) + (1\times2^{-3})$$

$$(10110\ .\ 001)^2 = (1\times16) + (0\times8) + (1\times4) + (1\times2) + (0\times1)\ .\ (0\times1/2) + (0\times1/4) + (1\times1/8)$$

$$(10110\ .\ 001)_2 = 16 + 0 + 4 + 2 + 0 + 0 + 0\ .\ 0.125$$

$$(10110\ .\ 001)_2 = (22\ .\ 125\ )_{10}$$

Hexa-decimal to Decimal Conversion

- The process of converting hexadecimal to decimal is the same as binary to decimal. The process starts from multiplying the digits of hexadecimal numbers with its corresponding positional weights. And lastly, we add all those products

Example : $(152A.25)_{16}$

We multiply each digit of 152A.25 with its respective positional weight, and last we add the products of all the bits with its weight

$$(152A.25)_{16} = (1\times16^3) + (5\times16^2) + (2\times16^1) + (A\times16^0) + (2\times16^{-1}) + (5\times16^{-2})$$

$$(152A.25)_{16} = (1\times4096) + (5\times256) + (2\times16) + (10\times1) + (2\times16^{-1}) + (5\times16^{-2})$$

$$(152A.25)_{16} = 4096 + 1280 + 32 + 10 + (2\times1/16) + (5\times1/256)$$

$$(152A.25)_{16} = 5418 + 0.125 + 0.01953125$$

$$(152A.25)_{16} = (5418\ .\ 14453125)_{10}$$

So, the decimal number of the hexadecimal number 152A.25 is 5418.14453125

Hexadecimal to Binary Conversion

The process of converting hexadecimal to binary is the reverse process of binary to hexadecimal. We write the four bits binary code of each hexadecimal number digit

Example : $(152A.25)_{16}$

We write the four-bit binary digit for 1, 5, A, 2, and 5

$$(152A.25)_{16} = (0001\ \ 0101\ \ 0010\ \ 1010\ .\ 0010\ \ 0101)_2$$

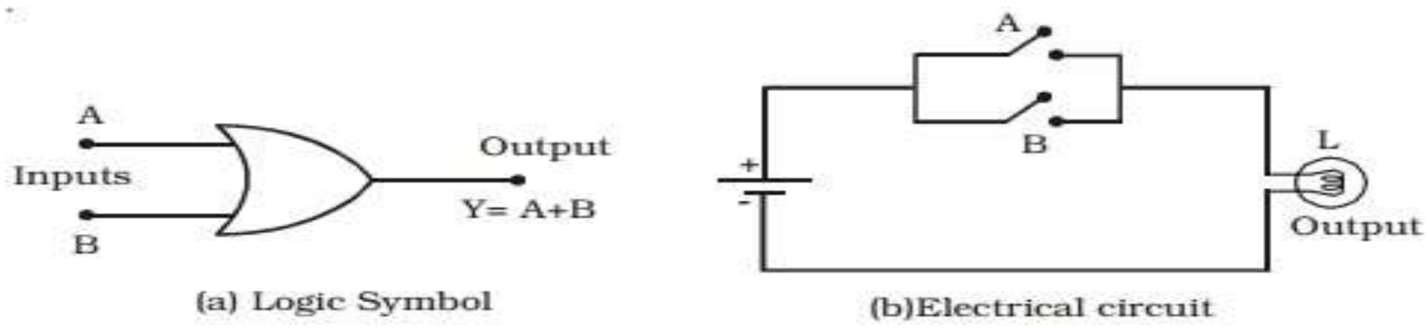
So, the binary number of the hexadecimal number

152A.25 is $(1010100101010.00100101)_2$

Basic logic gates using discrete components

The basic elements that make up a digital system are 'OR', 'AND' and 'NOT' gates. These three gates are called basic logic gates. All the possible inputs and outputs of a logic circuit are represented in a table called TRUTH TABLE. The function of the basic gates are explained below with circuits and truth tables

(i) **OR gate:** An OR gate has two or more inputs but only one output. It is known as OR gate, because the output is high if any one or all of the inputs are high. The logic symbol of a two input OR gate is shown in Fig



(a) Logic Symbol (b)Electrical circuit

Fig OR gate

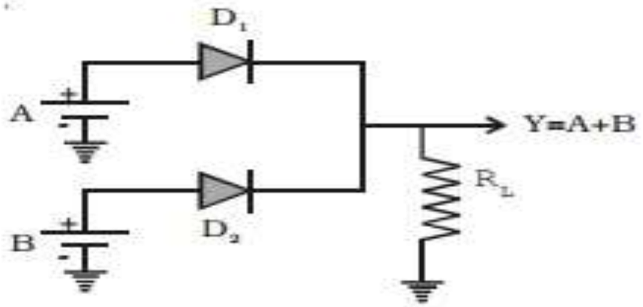


Fig OR gate using diodes

Table Truth table of OR gate

Inputs		Output
A	B	Y = A + B
0	0	0
0	1	1
1	0	1
1	1	1

- The Boolean expression to represent OR gate is given by Y= A+B (+ symbol should be read as OR)

- Case (i) A = 0 and B = 0

  When both A and B are at zero level, (i.e.) low, the output voltage will be low, because the diodes are non-conducting

- Case (ii) A = 0 and B = 1

  When A is low and B is high, diode D2 is forward biased so that current flows through RL and output is high

- Case (iii) A = 1 and B = 0

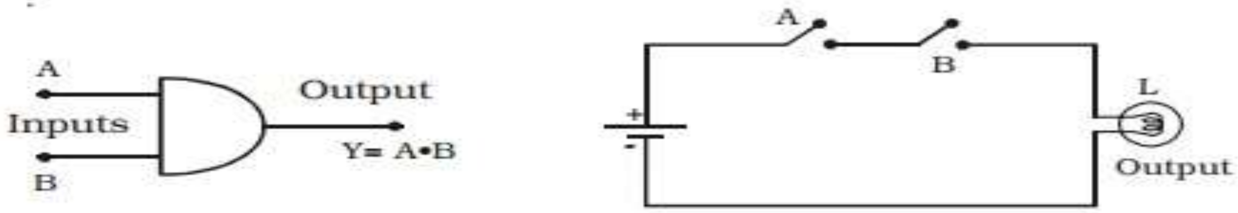
  When A is high and B is low, diode D1 conducts and the output is high

- Case (iv) A = 1 and B = 1

  When A and B both are high, both diodes D1 and D2 are conducting and the output is high. Therefore Y is high

(ii) AND gate

- An AND gate has two or more inputs but only one output. It is known as AND gate because the output is high only when all the inputs are high. The logic symbol of a two input AND gate is shown in Fig. Y = A·B (· should be read as AND)



(a) Logic symbol *(b) Electrical Circuit*

Fig AND gate

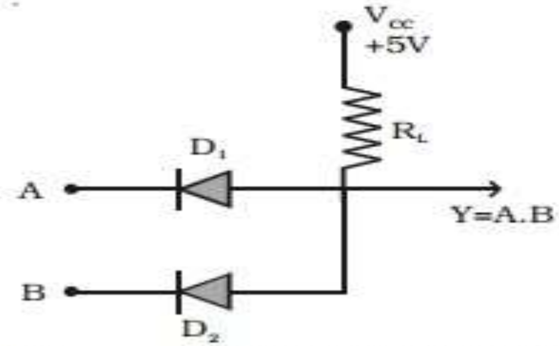


Fig AND gate using diodes

Table Truth table of AND gate

Inputs A	Inputs B	Output Y = A · B
0	0	0
0	1	0
1	0	0
1	1	1

Fig shows a simple circuit using diodes to build a two-input AND gate. The working of the circuit can be explained as follows

- Case (i) : A = 0 and B = 0

  When A and B are zero, both diodes are in forward bias condition and they conduct and hence the output will be zero, because the supply voltage VCC will be dropped across RL only. Therefore Y = 0

- Case (ii) : A = 0 and B = 1

  When A = 0 and B is high, diode D1 is forward biased and diode D2 is reverse biased. The diode D1 will now conduct due to forward biasing. Therefore, output Y = 0

- Case (iii) : A = 1 and B = 0

  In this case, diode D2 will be conducting and hence the output Y = 0

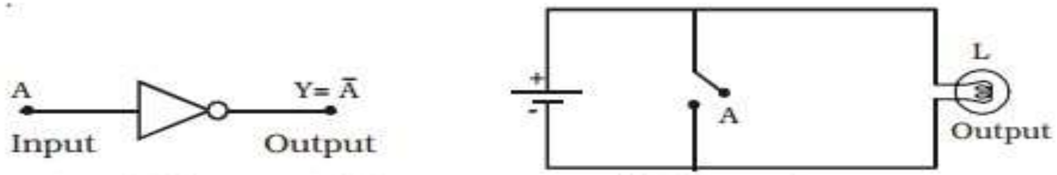
- Case (iv) : A = 1 and B = 1

  In this case, both the diodes are not conducting. Since D1 and D2 are in OFF condition, no current flows through RL. The output is equal to the supply voltage. Therefore Y = 1

(iii) NOT gate (Inverter)

The NOT gate is a gate with only one input and one output. It is so called, because its output is complement to the input. It is also known as inverter. Fig a shows the logic symbol for NOT gate. The Boolean expression to represent NOT operation is Y = $\bar{A}$

- Fig is a transistor in CE mode, which is used as NOT gate



(a) logic symbol (b) Electrical circuit

Fig NOT gate

- When the input A is high, the transistor is driven into saturation and hence the output Y is low

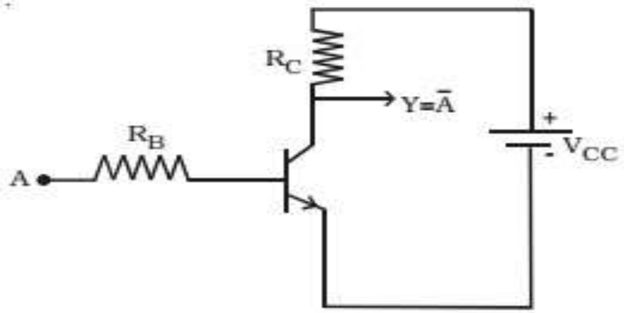


Fig NOT gate using transistor

Table 9.3 Truth Table of NOT gate

Input A	Output Y = $\bar{A}$
0	1
1	0

- If A is low, the transistor is in cutoff and hence the output Y is high. Hence, it is seen that whenever input is high, the output is low and vice versa