Sanjivani University
School of Engineering and Technology

Applied Science (24UETBS102)
Unit 1
Introduction to Fundamental Physics

Content:

Waves and Oscillation:*Types of Waves, Superposition of Waves, Standing Waves (Nodes and Antinodes), , and Its Applications.*

SHM*: Wave Equations, Simple Pendulum (Problems).*

Electrodynamics: *Faraday's Laws, Lenz's Law, Biot-Savart Law, Physics of Divergence, Gradient, and Curl, Magnetic Field, Vector Potential, Maxwell Equations (Qualitative).*

Semiconductor Electronics: *Band theory of solids, Energy band diagram, Semiconductor: Properties, Type, P-N Junction diode and applications, I-V characteristics, P-N-P and N-P-N transistors,*

Modern Physics: *Photoelectric Effect, Einstein's Photoelectric equation, Photocell(working), Solar cell.*

Ancient Astronomical Instruments: *Chakra, Dhanuryantra, Yasti and Phalak Yantra etc.*

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1. Waves and Oscillation
Introduction:

Wave is nothing but an oscillatory disturbance produced in the medium.
A means by which disturbances are transmitted from one region to another is called as **wave motion**.

Example
Sound spread in a hall
Stone dropped in a pond having still surface.

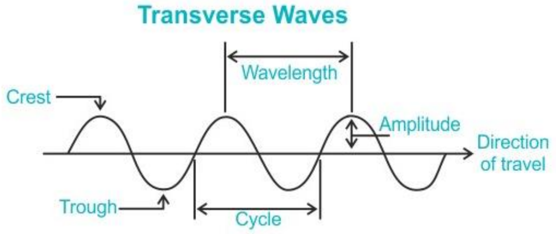
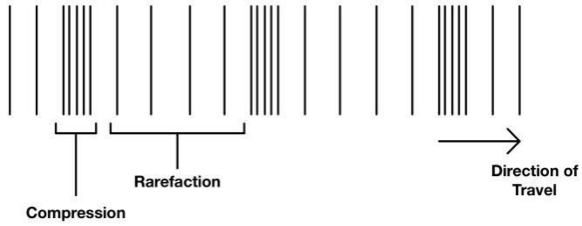
In wave motion only energy is transferred however no part of medium is transported in the medium.

Waves can be classified into different types based on their characteristics and the medium through which they travel.

Mechanical Waves: Mechanical waves require a medium (such as air, water, or solids) to travel through.
Example sound waves

Electromagnetic waves: Waves which do not require material medium for their propagation
Example: Light Waves

Progressive Wave: The wave which travel continuously in a given direction without change of form is called as progressive wave.
There are two types of progressive waves

Sr. No	Transverse wave	Longitudinal wave
1	A wave in which particles of the medium vibrate in a direction perpendicular to the direction of propagation of wave.	A wave in which particles of the medium vibrate in a direction parallel to the direction of propagation of wave.
2	Light wave	Sound wave
		
3	Do not require medium	Requires medium Medium should posses property of elasticity of volume I. e. Bulk modulus

Surface Waves: These waves travel along the surface of a medium and have characteristics of both transverse and longitudinal waves.
Example
Water waves.

Recall concepts

Amplitude: Maximum displacement from mean position. SI unit m
Frequency: Number of oscillations performed per second. SI unit Hz
Time Period: Time required to complete one oscillation SI Unit second

T=1/n
Wavelength: Distance covered by wave in one complete oscillation. SI Unit m
Or
Distance between two succesive compression or rarefactions. (in longitudinal wave)
Or
Distance between two succesive crests and troughs (In transverse wave)

Velocity of wave: Distance traveled by wave in one second.
SI unit m/s

Relation between velocity wavelenght and frequency

$$\boxed{V = n\lambda}$$

λ =wavelength
V= velocity
n= frequency

Electromagnetic Waves: Waves which do not require a medium .
They are created by the oscillation of electric and magnetic fields and include:

Light waves: Travel with a velocity of 3×10^8m/s
Radio Waves: Used in communication systems, such as radio and television broadcasts.
Microwaves: Used in microwave ovens and radar technology.
Infrared Waves: Experienced as heat and used in remote controls and thermal imaging.
Visible Light: The portion of the electromagnetic spectrum visible to the human eye.
Ultraviolet Light: Beyond the visible spectrum, used in sterilization and fluorescent lighting.
X-Rays: Used in medical imaging and security scanners.
Gamma Rays: Emitted by radioactive materials and used in cancer treatment and imaging.

Superposition of waves:

Principle:

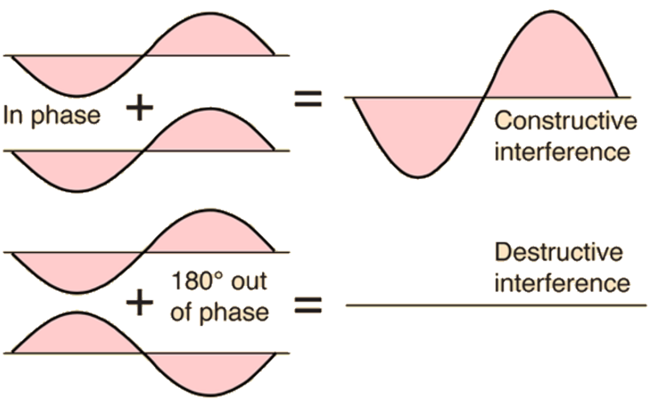
When two waves propagates simultaneously in a medium the displacement of the particles in the medium at any instant of time is the algebric sum of the displacement caused by the individual waves.

Example :
If two musical instruments are palyed simultaneously on stage like sitar and tabla , the audience can clearly distinguish the sound of these instruments.

Principal of Superposition can be used to study
- Interference
- Beats
- Stationary waves

Intereference:

When two sound waves of same amplitude and frequency travel simultaneously in a medium, the resulting wave has an intensity different from that of the individual waves. It is louder at some place whereas there is complete silence at some place.This is called as intereference.
https://www.acs.psu.edu/drussell/Demos/superposition/superposition.html

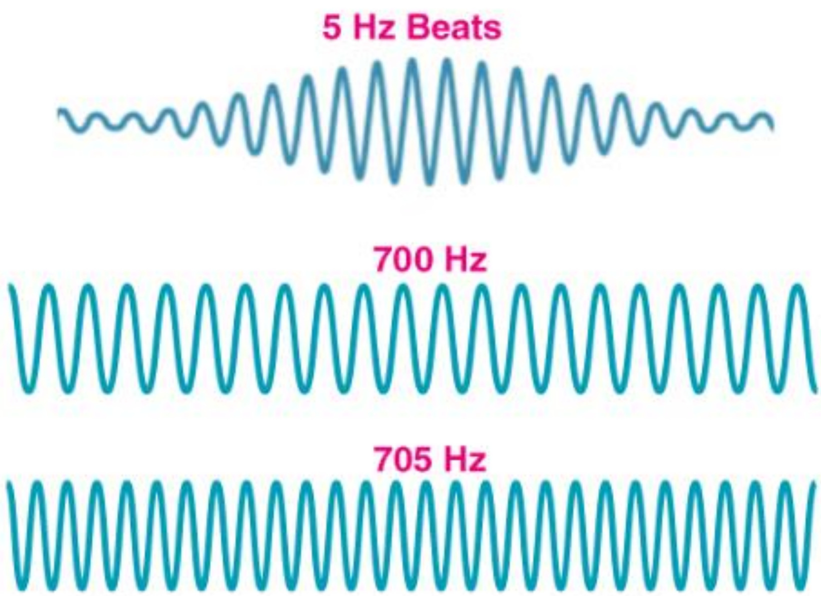


Interference of waves

Beats:

When two sound waves of same amplitude but slightly different frequencies travel in a medium along the same direction, the resultant amplitude is alternately maximum and minimum. They produces resultant sound waves of varying intensities(waxing and wanning).

The phenomenon of waxing and wanning of sound is called as beats.



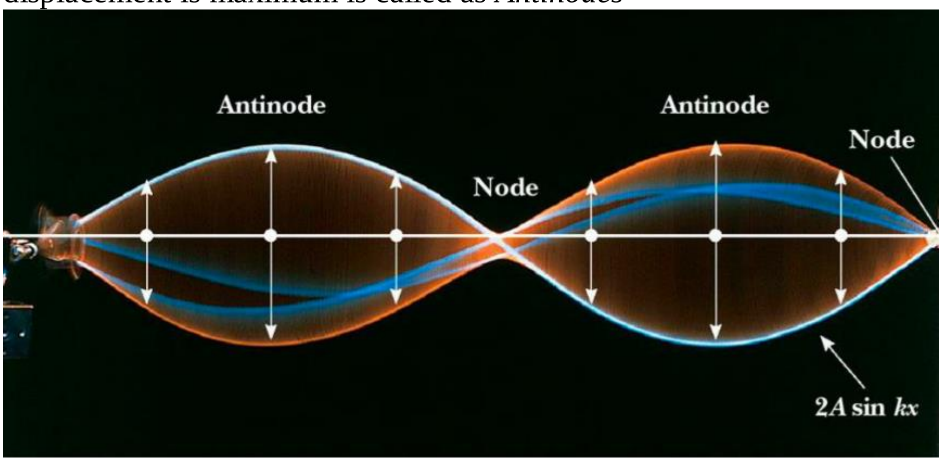
Formation of Beats   (https://byjus.com/physics/beats/)

Stationary Waves:

When the two identical progressive waves travel through a medium along the same line in opposite directions with the equal velocities, they superimpose over each other and produce a new type of wave called as stationary waves or standing waves along which is there is no transfer of energy.

Nodes : The points half a wavelength apart in a medium which are permanantly at rest are cslled as *Nodes.*

Antinodes: The points in medium mid way between the nodes, where the displacement is maximum is called as *Antinodes*



Stationary waves

Periodic motion:

Motion which repeat itself in equal interval of time is called as periodic motion.

Oscillations: To and fro motion along the same path is called as oscillatory motion

Example

Motion of hands of clock

Motion of simple pendulum

Motion of hands of a man walking

Simple Harmonic Motion:

A motion in which force (acceleration) is always directed towards mean position and magnitude is directly proportional to displacement from mean position.

e.g. Motion of needle of sewing machine

Vibration of string

Motion of prongs of tunning fork. etc

Let us consider a particle moving along a circle of radius a with a constant speed v

Wave Equations:

Sr. No	Particular		Mean Position	Extreme Position
1	Equation of displacement	$y = a\sin(\omega t + \alpha)$	$t = 0, \alpha = 0$ y =0 **Minimum**	$t = 0, \alpha = \frac{\pi}{2}\, or\, \frac{3\pi}{2}$ $y = \pm a$ **Maximum**
2	Equation of Velocity	$v = \frac{dy}{dt} = \frac{d}{dt}(a\sin(\omega t + \alpha)) =$ $v = aw\cos(\omega t + \alpha)$ $v = \omega\sqrt{a^2 - y^2}$	$t = 0, \alpha = 0$ $v = a\omega$ **maximum**	$t = 0, \alpha = \frac{\pi}{2}\, or\, \frac{3\pi}{2}$ $v = 0$ **minimum**
3.	Equation of acceleration	$acceleration = \frac{dv}{dt} = a\omega\cos(\omega t + \alpha)$ $acceleration = -a\omega^2\sin(\omega t + \alpha)$ $acceleration = -\omega^2 y$	$t = 0, \alpha = 0$ Acceleration=0 **Minimum**	$t = 0, \alpha = \frac{\pi}{2}\, or\, \frac{3\pi}{2}$ $acceleration = \pm a\omega^2$ **Maximum**

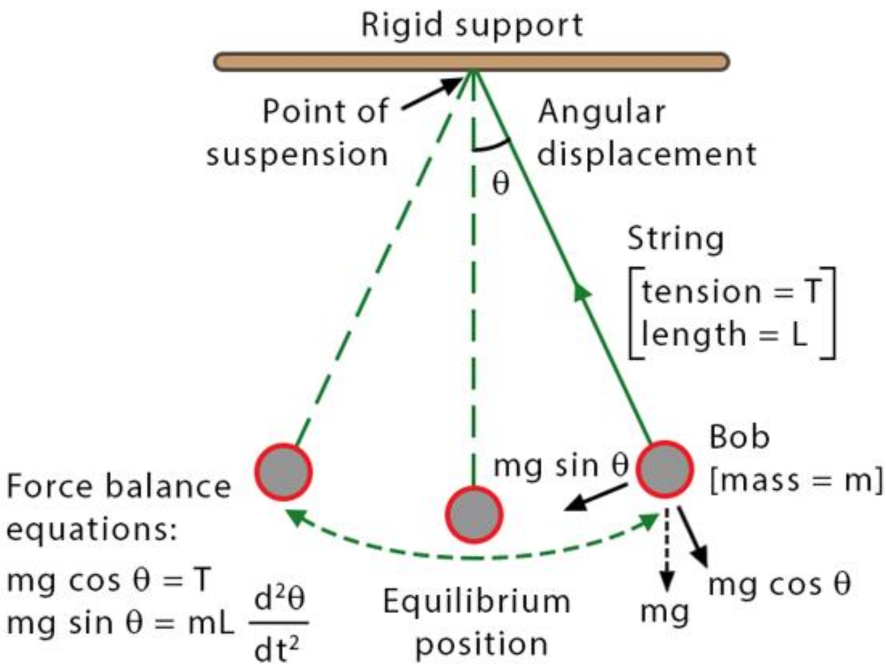
	Where, $y = displacement$ $v = velocity$ $a = amplitude$ $\alpha = epoch$ $\omega = angularvelocity$

Simple Pendulum:

Simple pendulum is the simplest form of oscillatory motion.

Ideal simple pendulum is a heavy particle suspended by a massless, inextensible flexible string from a rigid support.

Practical simple pendulum is a small heavy sphere suspended by a light and inextensible string from a rigid support.



Simple pendulum

Period for simple pendulum is…

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Simple pendulum performs linear simple harmonic motion for small amplitude.

Semiconductor Electronics:

Introduction:

Semiconductors are an essential component of electronic devices, enabling advances in communications, computing, healthcare, military systems, transportation, clean energy, and countless other applications.Due to their role in the fabrication of electronic devices, semiconductors are an important part of our lives. Imagine life without electronic devices. There would be no smartphones, radios, TVs, computers, video games, or advanced medical diagnostic equipment.

Band Theory of solids

- **<u>Introduction</u>** :- Atom is the fundamental unit of matter. It consist of centrally placed nucleus which consists of protons and neutrons in it and negatively charged electrons are revolving around nucleus in an elliptical orbit. Electrons in the inner shell (orbit) are bound to nucleus and hence called bound electron. The electrons in the outermost orbit are called valence electrons.
- **<u>Formation of Energy bands in solids</u>**:

  There are millions of electrons belonging to the first orbit of atoms in the solid having different energy levels which are closely packed. Thus closely spaced energy levels of millions of first orbit electrons forms a continuous band of energy and second orbit electrons forms second band.

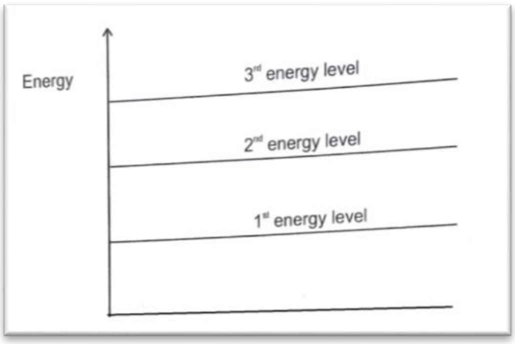


Fig. 1Energy level diagram of Atom

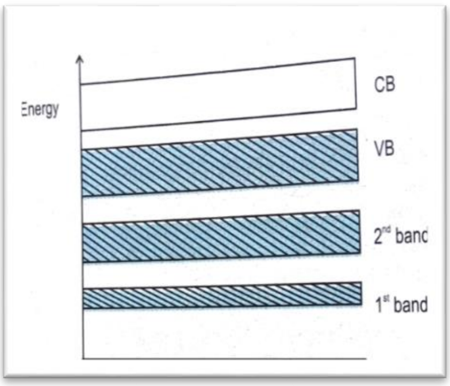


Fig. 2 Energy band diagram of solid

Q. Define energy band, valence band, conduction band, forbidden energy gap?

Energy band: The range of energies possesed by electrons of different atoms in solid is called as energy band.

Valence band: The range of energies possesed by electrons in the outermost orbit of an atom is called as valence band.

Conduction band : Valence electrons are loosely attached to the nucleus and can be detached and become free electrons. These free electrons in a conductor are responsible to carry current. They are called as conducting electrons.

"The range of energies possesed by conducting electrons is known as conduction band."

Forbidden energy Gap: The band (energy gap) between valence band and conduction band is called forbidden gap.

In order to lift the electrons from valence band to conduction band .Band gap energy (E_g) must be provided.

Energy of electron in an atom: In an atom various electrons are distributed in different orbits. In an orbit certain permissible values of energy apart from these energy levels.

Draw the energy band diagram for conductors, semiconductors and insulators.

Ans. **Conductor**: Metal (aluminium, silver, copper) contains large number of free electrons at room temperature. Hence conduction band and valence bands are overlapping each other. Hence forbidden energy gap is absent.

Semiconductors: Conductivity of semiconductor is greater than insulator and less than conductors.

Valence band is full and conduction band is almost empty, forbidden gap is very small of the order of 1eV.

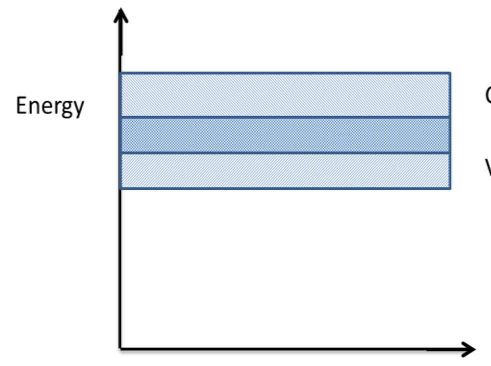
eg. Si and germanium.

Insulators: The forbidden energy gap is very high greater than 5 eV .The electrons cannot jump from valence band to conduction band.

Eg Glass, wood, rubber, plastic,etc.

Name two semiconductor which are commonly used.

Ans: **Silicon** and **germanium** are commonly used semiconductors.



Energy Band diagram of Conductor

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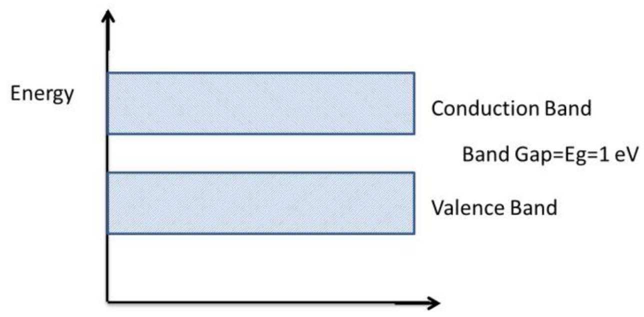
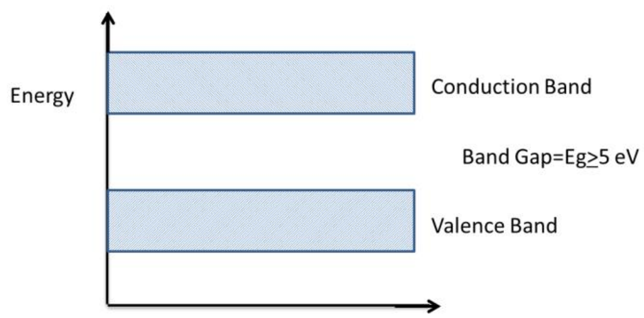


Energy Band diagram of Semiconductor



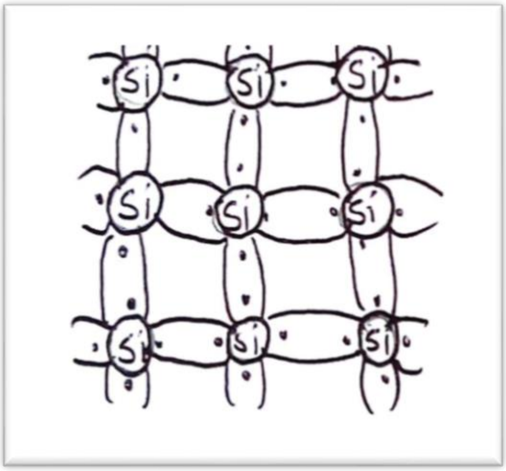
Energy Band diagram of Insulator

Define intrinsic semiconductor.

Ans: The semiconductor material in its purest form is called as intrinsic semiconductor.

(at 0 K)

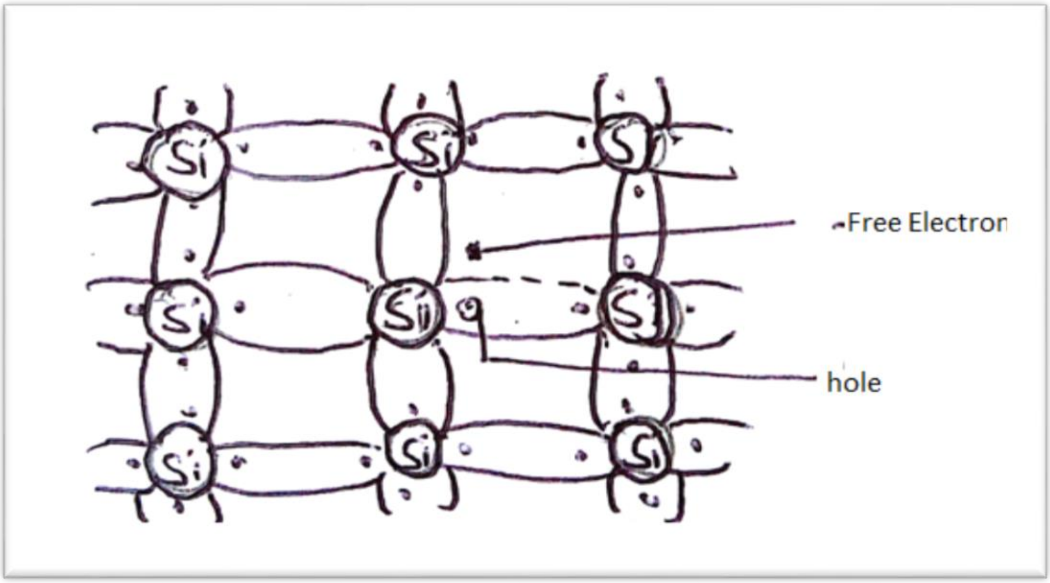
Explanation: At intrinsic semiconductor like pure silicon or germanium has four electrons in its outermost orbit of its atom. In order to fill valence shell atoms arrange themselves in such a way that each atom is surrounded by four atoms. This pattern is called as crystal. Each atom forms covalent bond with its four adjacent atom.



Intrinsic semiconductor At 0^0K

At absolute zero temperature there are no free electrons available for electrical conduction. **Semiconductor behaves as a perfect insulator at absolute zero temperature.**

At room temperature:-



Intrinsic semiconductor at room temperature

Room temperature is sufficient to break few covalent bonds. Thus few electrons are free to move in the crystal When electron moves away from atom vacancy is created i.e. hole in the bond which is positive charge . Hence free electrons and holes are generated simultaneously (in pairs). This is called as thermal generation.

What is the effect of temperature on conductivity of semiconductor?

Ans: As the temperature of semiconductor increases its conductivity increases.

Define Extrinsic semiconductor.

Ans: When suitable impurity is added to a pure semiconductor the type of semiconductor is called as extrinsic semiconductor.

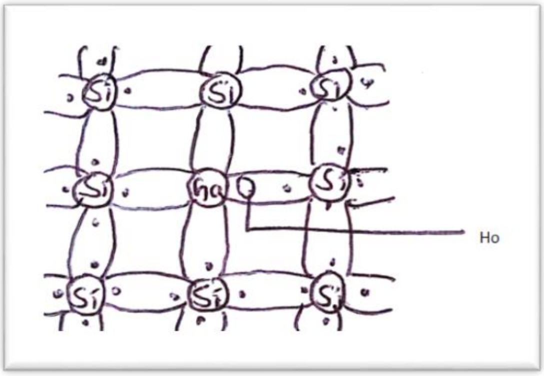
What is doping?

Ans: The process of adding impurity atoms in intrinsic semiconductor to increase its conductivity is known as doping .

- **p type extrinsic semiconductor:**

Ans: When a pure semiconductor is doped with the trivalent impurity it is called as P type semiconductor. (gallium, indium, aluminium).

Consider a pure silicon crystal. If trivalent impurity like Al, Ga is added to it then three valence electrons from each Si atom forms three covalent bands with Ga atom and instead of fourth bond electron a hole is created.



p-type semiconductor

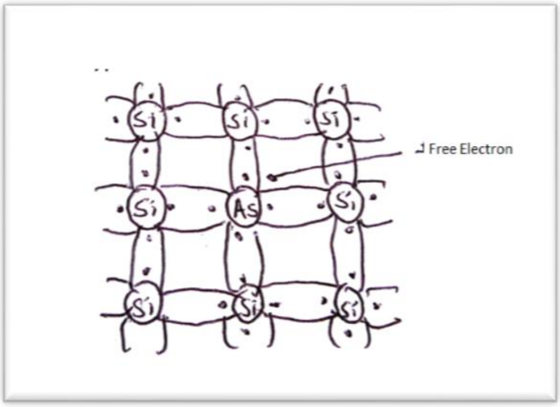
The **majority** carriers in p type are **holes** and impurity is called as **acceptor** impurity.

- **N type Extrinsic semiconductor**

When semiconductor is doped with pentavalent impurity it is called as n type semiconductor.(arsenic, antimony, phosphor) .

Consider a pure Si crystal If it is doped with pentavalent impurity like Arsenic (As) Antimony etc. which have five electrons in the outermost orbit, arsenic (impurity) atom forms four covalent bonds with Si atoms and fifth electron is extra and free in crystal.

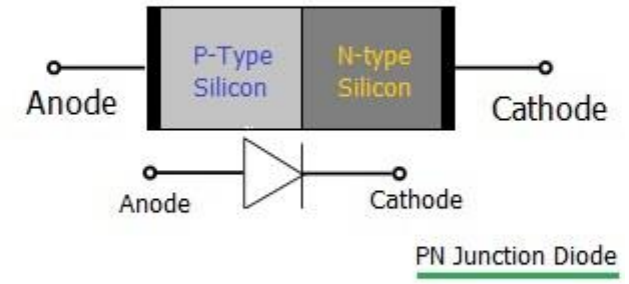
The **majority** carriers in N type semiconductor are **electrons** and impurity is called as **donor** impurity.



n- type semiconductor

PN junction Diode

When P Type semiconductor and N type semiconductor are joined together the structure so formed is called as **PN junction diode** . (Diode is a device which has two terminals)

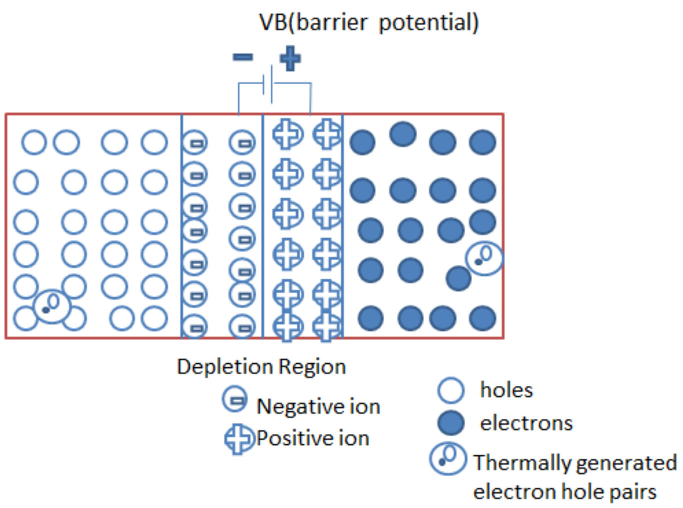


In P type semiconductor majority charge carriers are holes and in N type majority carriers are electrons.

When PN junction is formed, some electrons from N region cross the junction and diffuse into the P region. Recombination of holes and electrons takes place at the junction region creating +ve ions on N region and -ve ions on P region. After some time the process of recombination stops because of the formation of +ve and -ve ions on both sides of junction and that region is called as depletion region which is depleted of electrons and holes.

Due to the formation of +ve and -ve ions of PN junction an electric field V_B is produced at depletion layer called as **barrier potential** which acts as a small battery and opposes further diffusion of holes and electrons.(positive towards n-type and negative towards p-type)

Barrier potential for **silicon is 0.7** volts and for **germanium is 0.3volt .**



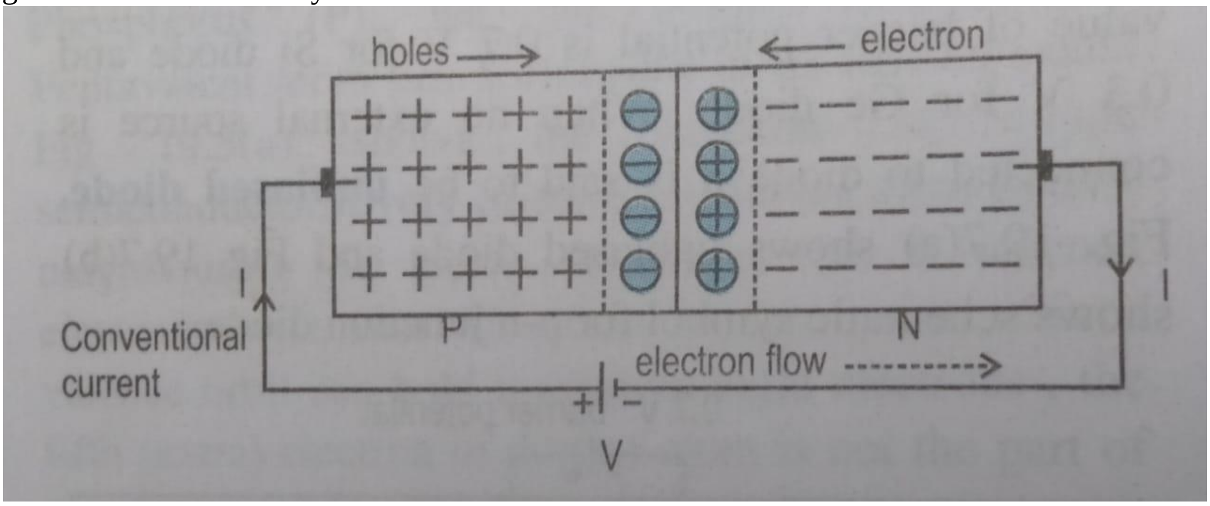
P-N junction diode

Biasing:--

Application of external DC supply to PN junction diode is called as biasing.
There are two types of biasing on PN junction diode .

Forward biased PN junction Diode:

If P region is connected to positive terminal of battery and N region is connected to negative terminal of battery the diode is said to be forward biased.



Forward Biased PN junction Diode

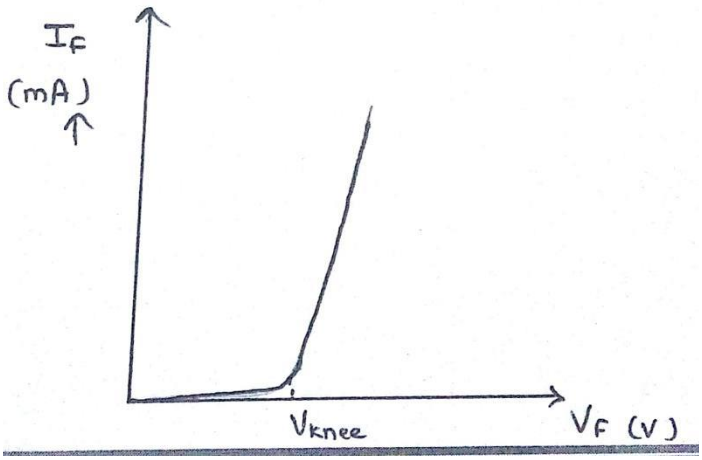
Working:-

Holes in the P region get repelled by +ve of battery and cross the junction and electrons in N region get repelled by - ve of battery and crosses the junction because of which diode conducts current.

The barrier potential V_B opposes the external battery. In order to flow current through diode. the external voltage supplied must be greater than VB i.e. 0.7 V for Si and 0.3 V for Ge. Because of pushing of charge carriers towards the junction, width of depletion layer decreases.

Forward Characteristics (IV Characteristics)

The plot of current Vs voltage is called as IV characteristics.

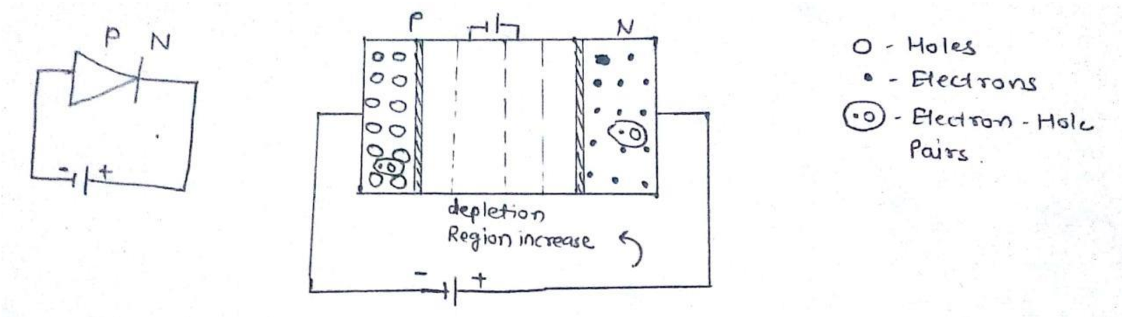


If external voltage is increased from zero onwards initially the forward voltage is increased and values of currents are recorded and graph is plotted.

When external voltage is less than 0.6 V a very few current in the circuit is set up. The diode current increases sharply beyond 0.6 V of external forward voltage .It is observed that forward voltage drop V_f is nearly constant as If increases.

Reverse Biased PN junction diode :-

If P type is connected to -ve terminal and N type is connected to +ve terminal of a battery the diode is said to be reverse biased.



Reverse Biased PN junction Diode

Holes in the P region gets attracted by - ve terminal and electrons in N region gets attracted by +ve terminal. Because of whuch charge carriers get away from the junction. Because of pulling away of charges from the junction width of depletion layer increases. The barrier potential VB assist the external battery.

Thus, reverse bias repels the majority carriers away from the junction i.e they cannot cross the junction and majority current carriers does not flow through the circuit.

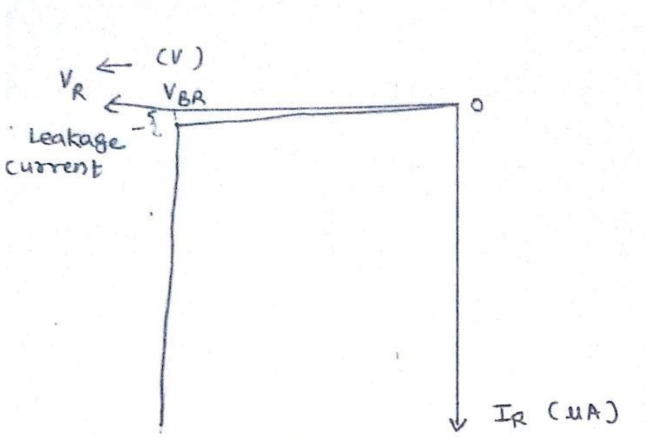
Though diode does not conduct the majority current carrier small amount of current flows through the reverse biased diode, called leakage current.

The leakage current is due to flow of minority carriers in both the regions. This flow of minority carriers is because of thermal energy.

By increase in temperature of diode the leakage current increases.

Reverse biased IV characteristics:--

Reverse biased voltage is increased and values of current are recorded and the graph is plotted.



The current which flows before breakdown VBR is because of thermally produced minority current carriers. This current is called leakage current which is microampere (μ A.)

As the reverse bias voltage is increased, at a critical voltage V_{BR} , the reverse current through the diode increases sharply. Most of the diode have breakdown voltage more than 50V.

Applications of PN Junction Diode

1. As a light source- LED (Light Emitting Diode)
2. A Detector- Photo Diode
3. In liquid Crystal Displays
4. As a rectifier
5. Regulator – Zener Diode
6. Switches

Static Resistance R_F:

The resistance offered by the diode to the forward DC operating conditions is called DC or Static Resistance.

$R_F = V_f/I_F$

Dynamic Resistance:

The resistance offered by the diode in AC operating conditions is called as Dynamic resistance.

Dynamic Resistance$=R_F=\triangle V_f/\triangle I_F$

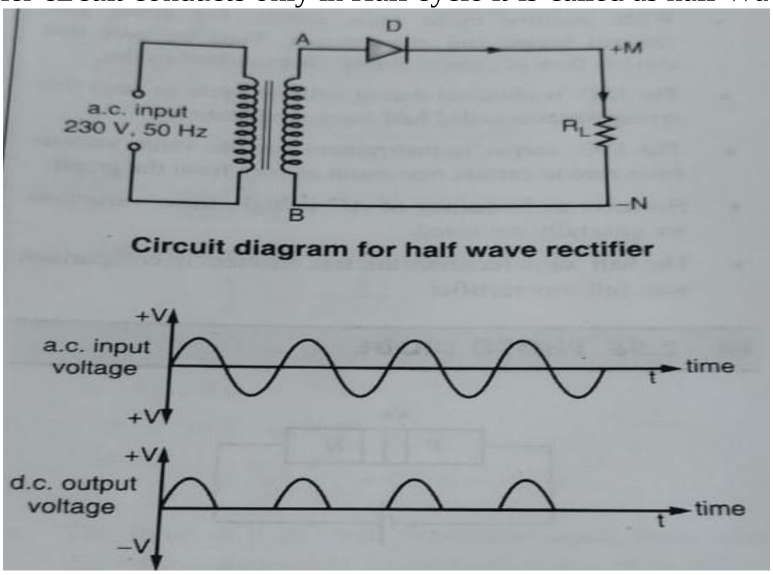
Half wave Rectifier:

Rectifier converts AC into DC(Alternating current/Voltage into direct current/ voltage)

Diode is used as a rectifier.

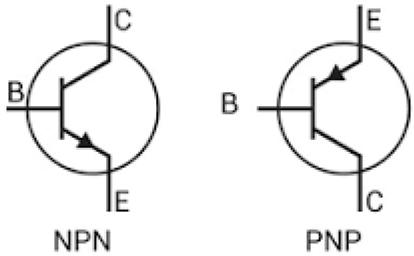
The half wave rectifier circuit is ON during one half cycle of the AC supply that is output is produced only in half cycle (Positive). During next half cycle output of rectifier is zero.

As rectifier circuit conducts only in Half cycle it is called as half Wave rectifier.



Transistor:

A transistor is a semiconductor crystal(silicon or Germenium) consist of three extrinsic regions doped by p-type and n type materials.
There are two types of tranasistors(Bipolar Junction Transistors).
PNP transistor: When a thin layer of p-type semiconductor is sandwitched between two n region

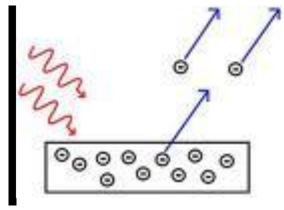


Photoelectric effect:

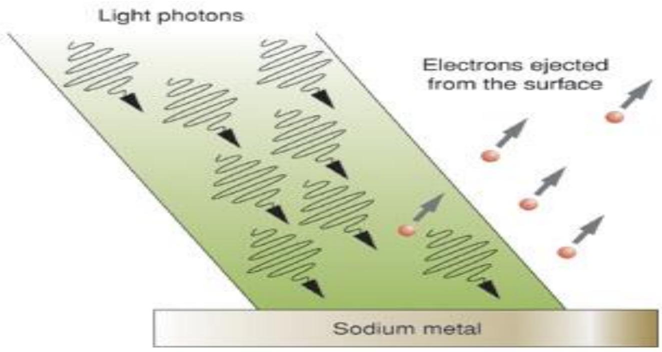
Introduction: Certain metals like magnesium, Zinc Lithium, when exposed to light, then electrons are emitted. Some alkali metals like Sodium, potassium are sensitive to even visible light. The electrons emitted are called as photoelectrons.

Photoelectric effect: “The emission of photoelectrons from metal surface, when light of suitable frequency (wavelength) is incident on it, is called as photoelectric effect ”.

Light energy ____conveted__________ Electrical energy
Into



The photoelectric effect was detected by Hertz in 1887. The phenomenon is also known as the "Hertz effect".



Planc’s hypothesis(Planc’s quantum theory)

According to Planc's hypothesis, energy is not emitted & absorbed continuously but in a descrete units or packets (bundle) called as Photon or quanta.
If ν is frequency of light, E is energy associated with photon, is directly proportional to frequency.

$E \alpha \nu$
$E = \text{constant} \times \nu$
$E = h\nu$

Where, h= Planc's constant.=6.63 x 10^{-34} Js

Statement:- "Energy is always emitted or absorbed in integral multiple of $h\nu$".

$E = nh\nu$ where n= integer.1,2,3

Concept of Photon?

According to Planc's hypothesis quantum or photon of light of frequency has energy $E=h\nu$

The light wave has minimum energy $h\nu$. & if it has more energy, it is integral multiple of $h\nu$.

Einstein proposed that when light falls on metal, energy $E=h\nu$ of photon is absorbed by the atom i.e. energy is transferred from light to atom ,called absorption of energy.

- when light of frequency ν is emitted by an atom energy $h\nu$ is transferred from atom to light i.e. emission.

Properties of Photon?

1. Photons are electrically neutral.
2. Photons travel with velocity of light. (3 x 10^8 m/s)
3. Radiation or light can be considered as shower of Photons.
4. Photons can not be deflected by magnetic field.

Characteristics of photoelectric effect

1. A metal emits electrons only when light of suitable frequency is incident on its surface called Threshold Frequency ν_0.
2. Photoelectric current is directly proportional to intensity of incident light. (i α I)
3. Velocity of photoelectron is directly proportional frequency. (v α ν)
4. This process is instantaneous. i. e. emission of photoelectrons starts at the moment light is incident on metal surface.

1. <u>**Threshold Frequency**</u> (ν_0):- Threshold frequency ν_0 of metal is minimum frequency of incident light at which emission just begins.
2. <u>**Threshold wavelength**</u>(λ_0):- Threshold wavelength λ_0 of metal is the maximum wavelength of light at which emission just begins.
3. <u>**Photoelectric work function**</u> (w_0):- Photoelectric work function w_0 of metal is energy required to detach the electron from metal.
4. <u>**Stopping potential**</u> (V):- Stopping potential of photoelectric cell is the negative potential given to cell at which photoelectric current becomes zero.

Applications of photoelectric cell

1. Photoelectric cell is used in Lux meter. To measure intensity of light.

2. It is used for automatic control of traffic signals.
3. It is used to switch on & off street light automatically.
4. It is used in recording & reproduction of sound during shooting of a film.
5. Photoelectric cells are used in television sets, fire alarm.
6. It is used in detecting flaws in metal.
7. Photoelectric cell is used in Burglar alarm

Einstein's photoelectric equations .

Radiation is considered as shower of photon. When radiation falls on metal, photon collides with metal atoms, & energy of photon ($h\nu$) is absorbed by atom. The part of this energy is used to detach the electron from the atom i.e. photoelectric work function (w_0) & remaining energy is used in giving kinetic energy to the electron (K.E.) i.e.

$$h\nu = w_0 + K.E.$$

$$h\nu = h\nu_0 + \frac{m}{2v^2} \qquad \text{[photoelectric work function } w_0 = h\nu_0 \text{]}$$

2

$$h\nu - h\nu_0 = \frac{m}{2v^2}$$

$$\boxed{\frac{m}{2v^2} = h(\nu - \nu_0)}$$

This equation is Einstein's photoelectric equation.

Where, m - mass of electron

v- velocity of electron

h- Planc's constant

ν - frequency of incident radiation

ν_0 -threshold frequency.

Cases:- In above equation

1. If $\nu < \nu_0$

K.E. is negative. & <u>no emission</u> takes place.

2. If $\nu = \nu_0$

K.E. is Zero. & <u>emission</u> just begins place.

3. If $\nu > \nu_0$

K.E. is positive. & <u>emission</u> takes place.

Hence as (ν) increases with increase in K.E. increases.

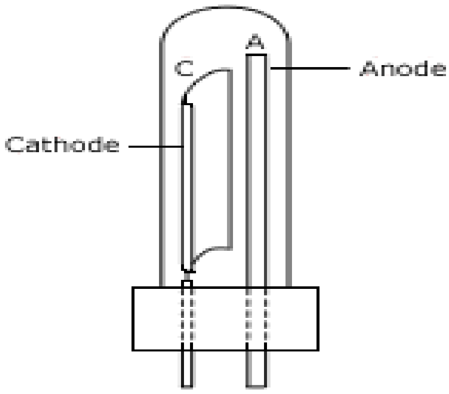
K.E. α Frequency.

Construction & working of photoelectric cell.

<u>Principle</u>: light energy is converted into electric energy.

<u>Construction</u>: Photoelectric cell consists of cathode K, anode A enclosed in a evacuated glass bulb. The semi cylindrical cathode coated with photosensitive material forms inner side. The anode is a platinum rod kept along the axis of cathode. Cathode (K) is connected to negative terminal & Anode (A) is connected to positive terminal of battery through milliameter.

Working: when light is allowed to fall on cathode it emits photoelectrons. These electrons are attracted by anode & photoelectric current flows through circuit & milliameter shows deflection.



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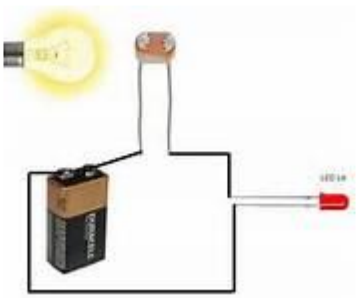
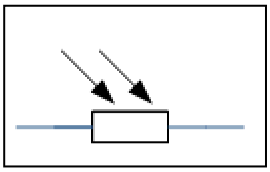
Cathode – ve
Anode +ve

Evacuated glass tube

Photoresistor
A photoelectric device is such device whose conductivity will increase with the increasing light intensity (Decrease in resistivity).

Principle
A photo resistor is made of a high-resistance semiconductor. When light of sufficiently high frequency falls on the device, its resistance decreases.
The semiconductor absorbs photons that transfer energy to bound electrons, causing them to jump into the conduction band. The resulting free electrons (and their hole partners) conduct electricity, thereby lowering resistance





Light Dependent Resistor Symbol

Principle
The resistance decreases as the intensity of incident light increases, and vice versa. In the absence of light, LDR exhibits a resistance of the order of mega-ohms which decreases to few hundred ohms in the presence of light.
It can act as a sensor, since a varying voltage drop can be obtained in accordance with the varying light. It is made up of cadmium sulphide (CdS).

Applications
Analog Applications
a. Camera Exposure Control
b. Auto Slide Focus - dual cell
c. Photocopy Machines - density of toner
d. Colorimetric Test Equipment
e. Densitometer

f. Electronic Scales - dual cell
g. Automatic Gain Control – modulated light source
h. Automated Rear View Mirror

2. **Digital Applications**
   a. Automatic Headlight Dimmer
   b. Night Light Control
   c. Oil Burner Flame Out
   d. Street Light Control
   e. Absence / Presence (beam breaker)
   f. Position Sensor

3. Light dependent resistors are a vital component in any electric circuit which is to be turned on and off automatically according to the level of ambient light - for example, solar powered garden lights, and night security lighting.

4. *An LDR can even be used in a simple remote control circuit using the backlight of a mobile phone to turn on a device - call the mobile from anywhere in the world, it lights up the LDR, and lighting (or a garden sprinkler) can be turned on remotely!*

Different forms of Einstein's Photoelectric equation

K.E= h (ν - ν_0)

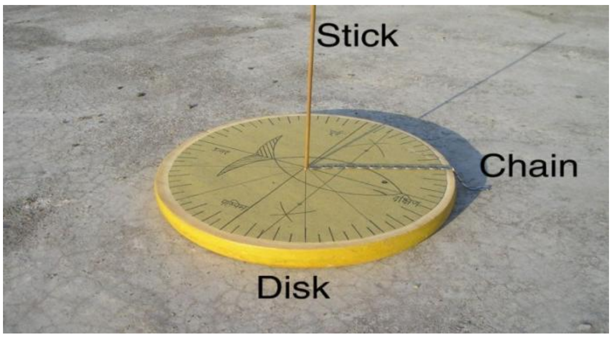
K.E= h c($\frac{1}{\lambda} - \frac{1}{\lambda_0}$) c= $\nu\lambda$, c= $\nu_0\lambda_0$

1. The photoelectric workfunction of certain metal is 10x 10^-19 J. Calculate threshold frequency.(h=6.63 x 10^-34).
2. The threshold frequency of a metal is 1.8 x10^15Hz.is made incident on the metal plate of frequency 1.8 x10^15Hz. calculate the maximum kinetic energy of the ejected photoelectron.

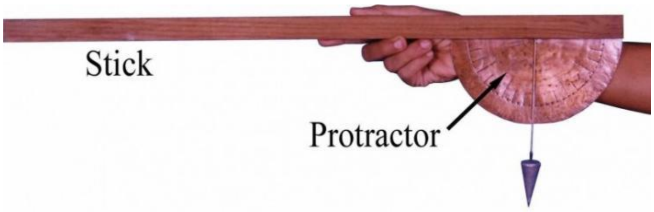
Ancient Astronomical Instuments

1. Chakra:

This instrument is a type of protractor used for angular marking of land and angular positioning of cities. It was also used to measure time and to measure some astrological parameters like 'natta' and 'unnatta'.



2. Dhanuryantra:

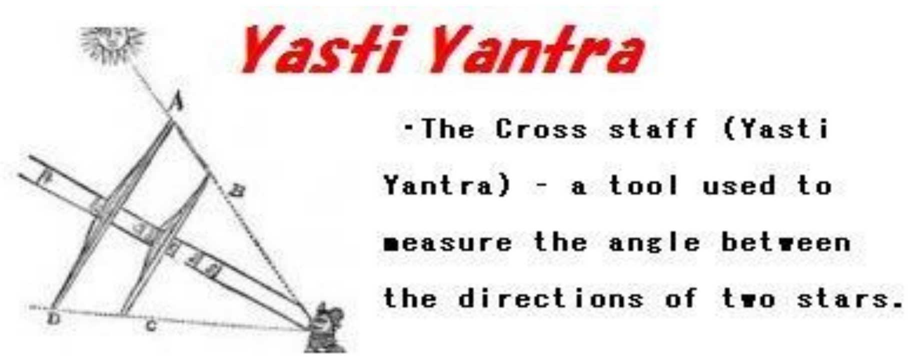


This machine is known as chaapa Yantra (Chaapa means a semicircle). Basically it was used for the measurement of vertical angle. Height of the terrestrial objects, diameter of earth, diameter of moon, circumference of earth and distance between moon and the earth was calculated by Bhaskaracharya using this instrument.

To calculate the height of the terrestrial object, stick was focussed at the bottom and top of the object and the angle was measured. This angle was then used to calculate the height with the help of jya and cotijya. This jya and cotijya are similar as sine and cosine resp.

Semicircular disk instrument of Bhaskaracharya known as chaapa yantra. This instrument appears to be the modified version of Dhanu Yantra of Lalla. Bhaskaracharya has attached a long stick along the diameter of the semicircular disk. Disk has the angular graduations and a pivoted chain at the center of the disk, this chain is used in similar way like a plumb bob. Description of this instrument is also given in Siddhanta Shiromani.

3. Yasti Yantra:



Bhaskaracharya has developed his unique method to calculate the height of terrestrial objects like trees and mountains.

This machine has a stick pivoted to a board. To use this machine one has to focus the top and bottom of the object and draw the two lines on the board. With these two lines, two triangles are constructed and based on their proportions, height of the object is calculated. It is to be noted here that there is no need to measure the distance between the object and the observer. This instrument was also used for land survey.

It is also refered as Dhi Yantra. Dhi Yantra means a machine to be used with intelligence. The principle and constructional details of this machine are available in fair detail in Siddhanta Shiromani of Bhaskaracharya .

4. Phalak Yantra:

It consist of a board. It is provided with a pin and an index arm.
This yanrta was used to determine time graphically by observing sun’s altitude.