Science :- The study about the physical world and natural laws.

Physics :- The scientific study of natural forces such as light, sound, heat, electricity, pressure, etc is called physics.

Material science :- The science that deals with the properties of materials like electrical, dielectric conduction, semi-conduction, magnetic, super-conductivity, optical etc, is known as materials science.

In terms of electrical properties, All materials can be divided into three groups:
(i) Conductors, (ii) semi conductors (iii) insulators.

Conductors :- The materials that conduct electricity when an electrical potential difference is applied across them are conductors.
on the basis of their conductivity, they can be classified into three categories.

(1) Zero resistivity materials
(2) low resistivity materials
(3) High resistivity materials

(1) Zero resistivity materials :- Superconductors like Alloys of aluminium, zinc nichrome etc, are a special class of materials that conduct electricity almost with zero resistance below transition temperature. These materials are known as zero resistivity materials

They are used for energy saving in power system superconducting magnets, memory storage elements etc.,

(2) Low Resistivity Materials: The metals and alloys like silver, aluminium have very high electrical conductivity. These materials are known as low resistivity materials.

They are used as resistors, conductors, winding wires in motors and transformers.

(3) High Resistivity Materials: The materials like tungsten, platinum, nichrome etc., have high resistivity and low temperature co-efficient of resistance. These materials are known as high resistivity materials.

They are used in heating elements, resistance thermometers etc.

Free Electron Theory:- The electron theory of materials aims to explain the structure & properties of solids through their electronic structure. This theory explains, binding, behaviour of conductor, & insulators, ferromagnetism, electrical and thermal conductivity, elasticity cohesive, and Rebulsive force.

This theory has been divided into three stages.

(i) classical free electron theory
(ii) The quantum free electron theory
(iii) The Zone (Band) theory.

The classical free electron theory:-

* The classical free electron theory was developed by Drude and Lorentz in 1900.
* He assumed that free electrons CAs a gas of electrons obey the laws of classical mechanics
* molecules of a gas as identical solid spheres which move along straight line until they collide with one another.
* In metal, there must be two types of particles for the electrons are negatively charged, and the metal is electrically neutral.
* Drude assumed that the compensating positive charge was attached to much heavier particles, which he considered to be immobile.
* When atoms of metallic elements are brought together to form a metal, the valence electrons from each atom become detached and wander freely through the metal, while the metalic ions remains intact and play the role of immobile positive particles
* A few of electrons Z are the relatively weakly bound valence electrons. The remaining (Za-Z) electrons are relatively tightly bound to the nucleus are called core electrons.
* The density of electron can be calculated as

The no. of electrons per cubic meter $n = \frac{N}{V} = 6.023 \times 10^{23} \times \frac{\rho_m Z}{A}$

A is atomic mass, ρ_m is mass density.

Inspite of strong electron-electron & electron-ion interaction, Drude model treats the dense metallic electron gas by method of Kinetic theory with only slight modifications.

The basic assumptions are following.

(1) Collisions and interactions of one electron with another electron & ion are neglected. Each electron moves freely.

(2) The neglect of electron-electron interaction b/w collisions is known as "independent electron approximation". The neglect electron-ion interactions is known as the "free electron approximation".

(3) In presence of EM field, the electrons acquire some amount of energy and are directed to move towards higher potential. As a result electrons acquire a constant velocity known as drift velocity.

After collision, velocity of electron alter, which is called bouncing off the impenetrable ion cores.

* The probability of an electron undergoing collision in time interval τ of length ds is $= \frac{ds}{\tau}$
* τ is known as relaxation time or mean free time.
* Electrons are assumed to achieve thermal equilibrium with their surrounding through collision.
* After each collision, Area will be hotter and electron will emerge with faster velocity.

Success of classical free electron theory:-

1. It is used to verify ohm's law
2. It is used to explain electrical and thermal conductivity of metals
3. It is used to explain the optical properties.
4. Ductility and malleability of metals can be explained by this model.

Drawbacks of classical free electron theory:-

1. A/c to classical theory specific heat of metal is 4.5R, but experimental value is nearly equal to 3R.
2. We can not explain for electrical conductivity of semiconductors or insulators using this theory.
3. Theoretical value of paramagnetic susceptibility is greater than the experimental value
4. Ferromagnetism can not be explained by this theory
5. A/c to classical theory $\frac{K}{\sqrt{T}}$ is constant at all temp but it is variable at low temp.
6. The photo electric effect, Compton effect and the black body radiation can not explained by the classical free electron theory.

Quantum free Electron Theory

de Broglie wave Concepts:- A/c to de Broglie "Light exhibits dual nature". Light behave as a wave as well as particle. Louis de Broglie, put forward the suggestion that "matter also exhibits dual nature".

A/c to de-Broglie.

(i) The Universe is made of radiation and matter.

(ii) Every moving particle shows dual nature. The wave associated with a moving material particle are called matter waves or de-Broglie wave.

The wave length of matter wave $\lambda = \frac{h}{mv} = \frac{h}{p}$

where h is the planck's Constant.

Schrodinger derive two equation to calculate the total energy and the nature of matter wave are as follows:-

Schrodinger Time-independent wave equation

$$\nabla^2\psi + \frac{2m}{\hbar^2}(E-V)\psi = 0$$

Schrodinger Time dependent wave equation

$$\left(-\frac{\hbar^2}{2m}\nabla^2 + V\right)\psi = i\hbar\frac{\partial\psi}{\partial t}.$$

$$H\psi = E\psi$$

where $H = -\frac{\hbar^2}{2m}\nabla^2 + V$ = Hamiltonian operator

$E = i\hbar\frac{\partial}{\partial t}$ = Energy operator.

and ψ = wave function & $\int \psi\psi^* d\tau$, Provide the probability of finding the particle at that time and at that point.

The Salient features of quantum free Electron Theory.

- Sommerfield proposed this theory in 1928
- He retained the concepts of free electrons moving in uniform potential within the metal as in classical theory, but treated the electrons as the laws of quantum mechanics.
- On the de Broglie wave concept, he assumed that moving electron behaves as if it were a system of wave (matter wave).
- A/c to quantum mechanics, the energy of an electron in metal is quantized.
- No two electrons will have the same set of quantum numbers.
- Each energy level can provide only two state; one with spin up and other with spin down.
- So, it is assumed that the permissible energy state of free electron are determined.
- It is assumed that the valance electrons travel in constant potential inside the metal but they are prevented from escaping the crystal by very high potential barrier at the end of crystal.
- In this theory, though the energy level of the electrons are discrete, the spacing between consecutive energy level is very less thus the distribution of Energy level seems to be continuous.

Success of quantum free electron theory:-

- A/c to classical theory, which follows Maxwell-Boltzman statics, all the free electrons gain energy. But A/c to quantum mechanics only one percent of free electrons can absorb energy so resulting specific heat and paramagnetic susceptibility values are in much better agreement with experimental values.

- A/c to quantum free electron theory, both experimental and theoretical values of Lorentz number are in good agreement with each other.

Drawbacks of quantum free electron theory.

- It is incapable of explaining why some crystals have metallic properties and others do not have.
- It fails to explain why the atomic arrays in crystals including metals should prefer certain structures and not others.