PHYSICS FOR INFORMATIONS SCIENCE

UNIT – I

PROPERTIES OF MATERIALS

Part A

1. Define ELECTRICAL conductivity?

Electrical conductivity is defined as the quantity of charge flowing across per unit time under unit potential gradient.

Its unit is $ohm^{-1}\ m^{-1}$

2. Define 'mean free path' and 'Drift Velocity'.

The average distance travelled between two successive collisions is called the Mean free path.

Drift Velocity (V_d) is the average velocity acquired by the free electron in a particular direction due to the application of electric field.

3. Give the postulates of classical FREE ELECTRON THEORY.

(I) A Solid metal is composed of atoms and the atoms have nucleus around which there are revolving electrons.

(ii) In the absence of an electric field, the free electrons move in random directions and collide with positive ions fixed to the lattice or other free electrons. All the collisions are elastic.

(iii) When an electric field is applied to the metal, the free electrons are accelerated in the direction opposite to the direction of applied electric field.

4. Define 'mobility of electrons'.

Mobility of electrons is defined as the drift velocity gained by the electron per unit electric field strength.

$$\mu = \frac{V_d}{E}$$

5. Distinguish between relaxation time and collision time.

Relaxation Time	**Collision Time**
1. The average time taken by the free electron to Reach its equilibrium state from its disturbed state due to the applied field.	The average time taken by the free electron between two successive collisions.
2. Relaxation time is approximately equal to 10-14 Second.	Collision time (τ_c) is given by $\tau_c = \frac{\lambda}{v_d}$

6. What are the merits of classical free electron theory?

- It is used to verify ohm's law.
- It is used to explain electrical and thermal conductivities of metals.
- It is used to derive Wiedmann – Franz law.
- It is used to explain the optical properties of materials.

7. Mention the demerits of classical free electron theory.

- Classical free electron theory states that all the free electrons will absorb energy, but quantum theory states that only few electrons will absorb energy.
- This theory cannot explain the Compton Effect, photo–electric effect and black body radiation.
- Specific heat variation with temperature is not explained.
- Atomic fine spectra could not be accounted.

8. What are the source of resistance in metals?

(i) Impurities present in the metals.

(ii) Temperature of the metal.

(iii) Number of free electrons.

9. State Wiedemann Franz law.

Wiedemann Franz law states that "The ratio of thermal conductivity to the electrical conductivity of a metal is directly proportional to the absolute temperature of the metal"

i.e, $\frac{K}{\sigma} \propto T$

10. What is Lorentz number?

The ratio between thermal conductivity (K) of a metal to the product of electrical conductivity (σ) of a metal and absolute temperature (T) of the metal is a constant. The constant L is known as Lorentz number and is given by

$$L = \frac{K}{\sigma T}$$

11. Give the postulates of quantum free electron theory?

- The potential energy of an electron is uniform or constant within the metal.
- The electrons have wave nature.
- The allowed energy levels of an electron are quantized.
- The free electrons obey Fermi - Dirac statistics.

12. Mention the merits of quantum free electron theory.

- Quantum free electron theory predicts the correct value of electrical conductivity, thermal conductivity and specific heat capacity of metals.
- It also explains photoelectric effect and Compton Effect.
- This theory is applicable for conductors, semiconductors and insulators.

13. What are the demerits of quantum free electron theory?

- It fails to differentiate between conductors, semiconductors and Insulators.

- It fails to explain the positive value of Hall coefficient and some of the transport properties of the metals.

14. How does classical free electron theory failed to account for specific heat of solid?

The value of specific heat of metals is given by 4.5 Ru where Ru is the universal gas constant whereas the experimental value is nearly equal to 3Ru. Since the theoretical and experimental value are not same, classical free electron theory failed to account for specific heat of solid.

15. Get the microscopic form of ohms law and state whether it is true for all temperatures?

According to classical free electron theory current density, $\mathrm{J} = \sigma \mathrm{E}$

Since, $\sigma = \frac{1}{\rho}$

$J = \frac{E}{\rho}$ Since, $E = \frac{V}{l}$

$J = \frac{V}{l\rho}$ Since, $J = \frac{I}{A}$

$\frac{I}{A} = \frac{V}{l\rho}$

$\mathrm{V} = \mathrm{I}\frac{l\rho}{A}$

Resistance, $R = \frac{\rho l}{A}$

$\mathrm{V} = \mathrm{I}R$ Since the resistivity varies with respect to the temperature, the microscopic form of ohm's law is not true for all the temperatures.

16. Write Fermi – Dirac distribution function and give its importance.

The probability F(E) of an electron occupying a given energy level at absolute temperature is called Fermi _ Dirac distribution function.

It is given by F (E) =$\frac{1}{1+e^{(E-E_F)/KT}}$

Where F (E) → Fermi function.

E → Energy of the level whose occupancy is considered.

E_F → Fermi energy of the system.

K→ Boltzmann constant.

T→ Absolute temperature.

Importance:

It gives the probability of filling the electron within the Fermi energy level.

17. Define Fermi level of a metal. Give its importance.

Fermi level is that level at which the probability of electron occupation is $\frac{1}{2}$ at any temperature above ok and also it is the highest level of the filled energy states at ok.

It is the reference energy level, which separates the filled energy levels and vacant energy level.

18. Define 'Fermi energy' of a metal. Give its importance.

Fermi energy is the energy of the state at which the probability of electron occupation is $\frac{1}{2}$ at any temperature above ok and also it is the maximum energy of the filled energy states at ok.

It determines the energy of the particle at any temperature.

19. What is a 'periodic potential'?

When an electron moves through a solid, its potential energy varies periodically with the periodicity equal to period of interatomic distance 'a'. This is called periodic potential.

20. Define 'density of energy states' and state its importance.

Density of energy states is defined as the number of energy states per unit volume of the material in an energy interval E and E+dE. It is denoted by Z(E)dE.

Importance: It is used to calculate the number of charge carriers per unit volume of any solid.

21. What are holes?

Holes are the vacant sites in the valence band of the solid. In the presence of applied electric field, they will behave like positive charge carriers having the mass of electron.

22. Explain the concept of hole and give its advantage.

When the electrons are accelerated in a periodic potential, its mass varies and it moves in the direction opposite to the direction of the applied field. This variation of mass of an electron is called as negative mass behaviour of electrons.

Advantage:

If there are 'n' number of empty states in a nearly filled band, then these 'n' number of empty states can be considered as 'n' number of holes.

23. Define effective mass of an electron.

Effective mass of an electron is the mass of the electron when it is accelerated in a periodic potential and is denoted by m^*.

24. What is meant by degenerate and non – degenerate states?

For several combinations of Quantum numbers if we have same energy Eigen value but different Eigen function, then such a state is called degenerate state.

For certain combination of quantum numbers, if there is only one wave function corresponding to the energy Eigen value, then such states are called non – degenerate state.

25. List out the three main theories developed for metals.

(i) Classical free electron theory:

Drude and Lorentz developed this theory in 1900. It is a macroscopic theory and it obeys classical laws.

(ii) Quantum free electron theory:

Sommerfield developed this theory in 1928. It is also a microscopic theory and it obeys quantum laws.

(iii) Zone theory (or) Band theory:

Bloch developed this theory in 1928. It is also a microscopic theory which is based on the energy bands of solids.

26. What are Fermions?

Fermi – Dirac statistics deals with the distribution of electrons among the various energy levels in a real materials. The electron are assumed to have half integral spin. Therefore, the electrons are called Fermions.

27. Fermi – Dirac statistics is applicable to which type of particles?

According to Fermi – Dirac statistics, the particle of the system is identical and indistinguishable. Since the particles of the system obey Pauli's exclusion principle, Fermi – Dirac statistics is applicable to particles having half integral spin angular momentum in units of $\frac{h}{2\pi}$.

28. What is f_k of an electron? Distinguish between conductors and semiconductors on the basis of f_k.

f_k Represents the degree of freedom of an electron, which is the measure of the extent upto which an electron can remain free in the given energy state.

$$f_k = \frac{m}{m^*}$$

Where m → free electron mass.

m^* →Effective mass of an electron.

For conductors, m = m^* (ie) f_k = 1 i.e., we have more number of free electrons.

For semiconductors m ≠ m^*, f_k ≠ 1.

29. Which statistics can be used for explain energy distribution in conductor? Write down the expression.

Fermi Dirac statistics can be used for explaining the energy distribution in conductor.

$$F(E) = \frac{1}{1+e^{(E-E_F)/KT}}$$

Where, E → Energy of the level whose occupancy is being considered

E_F → Fermi energy level

K → Boltzmann constant

T → Absolute Temperature.