CL24_Q1. Bring out the salient features of Drude-Lorentz theory and mention the drawbacks of the classical free-electron theory.

Answer

Drude and Lorentz developed the classical free electron theory, based on the following assumptions.

1. Metal atoms have some of the valence electrons freely moving about in the body of the metal. These electrons are called free electrons or conduction electrons, as they contribute to conduction in the metal.
2. The effect of positive ion cores on the electrons is considered to be constant and hence neglected.
3. The electrostatic repulsion between the electrons is neglected.
4. The free electrons move about identical with the motion of gas molecules and hence assumed to obey the kinetic theory of gases. In the absence of external electric field they are in random motion and their average kinetic energy is $\frac{1}{2} m v_{th}^2 = 3/2\ k\ T$, where v_{th} is the thermal velocity, k is the Boltzmann's constant and T is the absolute temperature.

Drawbacks of the classical free-electron theory

1. The classical free electron conduction model fails to explain the correct temperature dependence of resistivity of metals.
2. The theory fails to explain the actual specific heat dependence of electrons in metals.
3. The classical free electron theory fails to explain the dependence of electrical conductivity on electron concentration.

CL24_Q2. Distinguish between drift velocity and thermal velocity of an electron.

Answer

When an electric field is applied, the free electrons acquire a net constant velocity in a direction opposite to that of the electric field. This steady and very small velocity is called drift velocity v_d. The drift velocity is given by the relation $\boldsymbol{v_d = \frac{e\tau E}{m}}$ and is of the order of 10^{-4} ms^{-1}.

Whereas the average velocity of random motion of free electrons within the body of the metal in the absence of external field, is called thermal velocity $\boldsymbol{v_{th}}$. The thermal l velocity of electrons is given by $\boldsymbol{v_{th} = \sqrt{\frac{3kT}{m}}}$ and is of the order $10^5 ms^{-1}$

CL24_Q3. Calculate the drift velocity and thermal velocity of conduction electrons in copper at a temperature of 300 K, when a copper wire of length 2 m and resistance 0.02 Ω carries a current of 15 A. Given the mobility of free electrons in copper is 4.3 x 10^{-3} m^2/VS.(4M)

Answer

Solution: Given $\mu = 4.3 \times 10^{-3}\ m^2/VS$; T=300 K; L=2m ; I= 15A; R= 0.02 Ω

$$V_d = \mu E = \frac{\mu V}{l} = 6.45X10^{-4} ms^{-1}$$

$$\mathbf{v_{th} = \sqrt{\frac{3KT}{m}} = 1.16X10^5 ms^{-1}}$$

CL24_Q4. Using the free electron model derive the expression for electrical conductivity in metal.

Ans:

The current through a conductor with an electron concentration **n** of cross section ***A*** and length ***L*** at an applied electric field ***E*** can be evaluated as

$\boldsymbol{I = nev_dA}$ where v_d is the drift velocity given by $\boldsymbol{v_d = \frac{e\tau E}{m}}$

$\therefore \boldsymbol{I = neA\ \frac{e\tau E}{m}}$ **or** $\boldsymbol{J = \frac{I}{A} = \frac{ne^2\tau}{m} E = \sigma E}$ where $\boldsymbol{\sigma}$ is a constant for a given metal and is the conductivity of the metal

$$\boldsymbol{\sigma = \frac{ne^2\tau}{m} = ne\mu}$$