SEM - II

(1)

The electrical conductivity of Metals

Electron Drift in an Electrical field

According to the free electron theory, electrons move freely in a conductor. In the absence of an electric field, the electron gas is in an equilibrium distribution functions, viz, the Fermi-Dirac distribution function for a degenerate electron gas and the Maxwell-Boltzmann distribution function for non-degenerate electron gas (Fig. 1). Because of the the fact that in a conductor the no. of electrons moving in opposite directions ~~functions~~ is always the same, their average velocity in any direction is zero and consequently the distribution functions are symmetric about the axis of ordinates. This explain the fact that in the absence of an external electric field there is no electric current in a conductor, no matter how many free electrons it contains.

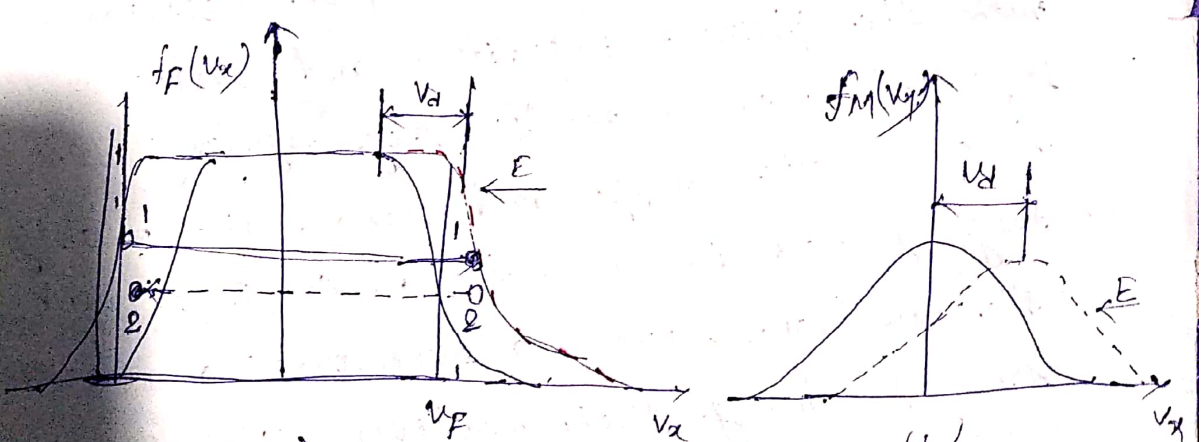

Fig. a) Fermi-Dirac & b) Boltzmann distribution function

When an electric field E is applied to a conductor, the random motion of the electrons gets modified in such a way that they drift slowly, in a direction opposite to that of the field, with an average drift velocity v_d. As a result, the distribution functions experience a change as shown by dotted lines in fig. (2). In order to calculate the drift velocity, let us consider a free electron in an electric field E. It will experience a force eE, which accelerates the electron according to Newton's second law of motion

$$a = \frac{eE}{m} \quad \text{— (1)}$$

Where e is the electronic charge and ~~m~~ m is the electronic mass, respectively. Prima facie, it appears that the electrons should be accelerated indefinitely and their velocity should grow continuously as a result of the electric field. However, this is not correct. In fact, during their motion the electrons collide with the phonons, impurities and lattice imperfections. As a result, they regularly lose their kinetic energy and hence the velocity they gained in the field. In other words, the electrons have to surmount a reaction force fr during their motion through the lattice. The reaction force is proportional to the drift velocity v_d and is directed against it.

$$f_r = -\frac{1}{\tau} m v_d \qquad \text{—— (2)}$$

where τ is called the relaxation time. Taking into account the eq^n. (1) & (2), the equation of directional motion of the electron in the lattice may be written as

$$m\frac{dv_d(t)}{dt} = eE - \frac{m v_d}{\tau} \qquad \text{—— (3)}$$

Eq^n. (3) tells us that the velocity of the directional motion of the electrons will rise and they will be accelerated until the two forces on the right-hand side become equal when the resultant force acting on the electron, and accordingly the acceleration will become zero. Consequently,

$$v_d = \frac{eE\tau}{m} \qquad \text{—— (4)}$$

Since an electron has a negative charge, it drifts in a direction opposite to that of the field.

In a chemically pure and structurally perfect crystal where the resistance force approaches zero, even a small field is enough to accelerate the electron indefinitely so that its velocity grows continuously which could become infinitely high. Actually, in a perfect lattice, electron wave propagates in an optically transparent medium.