SYNOPSIS OF THE WORK PRESENTED IN THIS THESIS

For systematic presentation of the results of our investigations in this thesis it has been divided into six parts or chapters.

A summary of the contents of these parts is given in successive order below.

Chapter I

Charge Transport in Semiconductors.

This chapter contains a résumé of charge transport in semiconductors. Assuming a model semiconductor with a parabolic conduction band, the Boltzmann transport equation is developed. Two methods for solving this equation are in vogue, 1) relaxation time approximation, 2) variation method. The first method is simpler and useful to derive many transport coefficients.

We have also considered the effect of the simultaneous action of an electric and magnetic field on charge transport. In this way the Bloch equation has been developed.

In using the relaxation time approximation all the different collision mechanisms that the carriers are subject to in a semiconductor have been considered and the relaxation time
for each process has been calculated. Thus for carrier scattering by acoustical phonons and ionized impurities etc. the relaxation time $\tau$ has been calculated. As relaxation time approximation is valid for quasi elastic scatterings and as the scattering by optical phonons is inelastic, a simple method for calculating $\tau$ in this case has been outlined.

Finally, we have derived expressions for current density, electrical conductivity, mobility, transverse magnetoresistance coefficient and Hall coefficient for material with realistic band structure.

**Chapter II**

**Mobility of Compensated Semiconductors.**

The mobility of charge carriers in doped semiconductors like $p$ and $n$-type Si and Ge has been investigated quite thoroughly. Especially, the influence of carrier scattering by ionized impurities on mobility has been a subject of theoretical and experimental study.

We have worked out a method which is applicable to the case of compensated semiconductors. As the carriers in such a materials are scattered by ionized impurities both positively and negatively charged, such charged impurities are considered to form electric dipoles especially in the case when the densities of both types of impurities are quite high and almost
of the same order. At very low temperatures the contributions of lattice scattering is negligible. So we have considered only scattering by dipoles embedded in a continuous dielectric medium and the scattering potential taken was a screened dipole potential. Our method differs from the previous works in the fact that we have calculated exactly the carrier mobility due to scattering by screened dipoles in a compensated semiconductors.

It is well known that the cross-section for scattering of electrons by dipoles increases with the number of dipoles formed. The probability of formation of dipoles increases with the increase of the density of impurities of both kind. So our results are expected to be applicable to the mobility of electrons in n-type compensated semiconductors with high doping. High doping generally means an impurity density \( \geq 10^{18}/\text{cm}^3 \). As we have not come across any experimental data on the variation of mobility of carriers in a highly doped compensated semiconductor with temperature at very low temperatures, we have not been able to compare our results with results found experimentally.

Chapter III

High Field Transport in Semiconductors.

This chapter contains an extension of the method developed in Chapter I. The emphasis here is on n-GaAs as a model of a semiconductor with a multi-valley conduction band with
non parabolic dispersion relation. The method is applicable to semiconducting material with similar properties.

The coupled Boltzmann equations for the electron distributions in $\Gamma_1$ and $X_1$ minima have been set up. The $\Gamma_1$ valley has been considered to be non-parabolic and the $X_1$ valley parabolic. The Boltzmann equations have been solved using a number of assumptions that seem to be reasonable for fields around the beginning of the negative differential resistance region, but should be quite good at higher fields. Intervalley, polar and other relevant intravalley scattering processes have been included. The effect of space charge scattering has also been considered.

From the solutions obtained we have calculated the variation of the valley populations and mobilities in each of the valleys, etc. as functions of the electric field. The results obtained here are used in our calculations in Chapter IV and V.

Chapter IV

Hall Effect in Hot Electron Conduction.

The Hall effect has played a decisive role in revealing the mechanism of carrier conduction in semiconductors. Especially, the anisotropy of the Hall coefficient in strong electric fields is of interest, particularly in view of the
changes in the carrier density in strong electric fields.

Plenty of experimental results show that the Hall coefficient changes in high electric fields even though the carrier concentration is not changing; but it has not yet been possible theoretically to account for the observed variation of Hall coefficient with electric field quantitatively. Many theoretical calculations have been done of galvanomagnetic properties in the many-valley model for particular scattering mechanisms, and for various ranges of temperature, electric and magnetic field strengths. Generally, these have involved solution of the Boltzmann transport equation, made treatable by simplifying assumptions about the scattering mechanisms, such as neglect of impurity scattering or intervalley scattering, or the assumption that the effect of intervalley scattering on energy and momentum loss can be neglected. These assumptions greatly limit the applicability of the calculations.

The values of the Hall coefficient we have calculated for n-GaAs have been plotted against electric field. The curve obtained by us has some peculiarities. For low values of the electric field it remains below the experimental curve and the theoretical curves obtained by others. It crosses the experimental curve at the critical field ≈ 3.5 KV/cm and remains almost constant for electric fields up to 7 KV/cm and shows a tendency of decreasing at higher values of the
electric field. Moreover, it is in better agreement with experimental results for values of electric fields greater than 3.5 KV/cm. In spite of the rudimentary form of our calculations it can be concluded that at values of electric field higher than 4 KV/cm the contribution to transport in n-GaAs is mainly due to the (0,0,1) valley electrons.

Chapter V

Plasma Frequency and Intervalley Population Transfer.

The properties of a plasma oscillations in a solid are determined by the values of the dielectric constant, the permeability, and the conductivity. Since we have not considered any magnetoplasma effect, we have taken permeability as unity and have studied the high-frequency conductivity and the high frequency dielectric constant to calculate the plasma frequency. Both approaches lead to the same result.

The plasma frequency in semiconductors at zero-electric field has been experimentally determined by optical-reflectivity measurements and Raman-scattering measurements. But the electric field dependence of the plasma frequency has not yet been determined experimentally.

However, we have calculated the plasma frequency as a function of applied field. In this calculation we have used the experimentally determined values of the drift velocity of electrons at different values of the electric field. We have
also compared our results with the existing theoretical calculations. It may be mentioned that up to threshold field (taken to be about 3 KV/cm) two curves agree but at higher fields our curve falls off less rapidly than that of the other workers.

It may also be mentioned that for quite high values of carrier density $n \approx 10^{18}/\text{cm}^3$, the plasmon-longitudinal optical phonon and plasmon-transverse optical phonon couplings influence the plasma frequency. The effect of these couplings have been taken into consideration in some recent works on optical reflectivity measurements and small angle Raman-scattering in determining the zero-field plasma frequency. In our simple calculations these effects have been totally ignored for the value of $n \approx 10^{16}/\text{cm}^3$ (Gunn oscillation region), as has been done by other theoretical workers.

Here our main aim has been to propose the study of the variation of plasma frequency with applied electric field for a quantitative estimation of intervalley population transfer.

Chapter VI

Study of a Simple Distribution Function of Hot Electrons.

The intervalley transfer of hot electrons in a semiconductor with a two-valley conduction band is studied here. The amount of transfer has been deduced by approximating
the energy distribution of the electrons by a Davydov distribution function. The results of our calculations have been compared with the results obtained recently by other workers and have been found to agree quantitatively at least at low electric fields. The disagreement at higher electric fields is somewhat prominent. This may be due to the following reasons.

a) We have considered both the conduction bands viz. \((0,0,0)\) and \((0,0,1)\) to be parabolic though it has been proved without any doubt that the central band is nonparabolic whereas the upper valley \((0,0,1)\) may be considered for all practical purposes to be parabolic.

b) The Davydov distribution function does not give the correct distribution for hot electrons. This point seems to us to be more plausible because this distribution function is isotropic and does not include optical phonon or impurity interactions and these interactions are known to be more prominent in the semiconductors considered here.