CHAPTER V

SUMMARY

The work described in the previous chapters can be divided into two main sections. The first deals with the effect of nonadiabaticity on charged particles and plasma during a single reflection. The second section deals with the study of nonadiabatic loss of charged particles trapped in a mirror trap.

5.1. Results from the Single Reflection Experiment:

Effect of nonadiabaticity was considered on a beam of electrons of low energy as well as on a plasma stream. During the course of this experiment, five different mirror configurations with different mirror ratios and different magnetic field scale lengths were used. The reflection coefficient was measured as the ratio of reflected current to incident current on the collector placed near the midplane of the system. These reflection measurements were supplemented with the floating potential measurements once again near the central plane with the help of a high impedance probe. The effect of magnetic field on the reflection coefficient was observed by increasing the base value of the magnetic field. Thus by varying the magnetic field the Larmor radius was changed while the magnetic field scale length remained same for a given field configuration. This amounted to changing the adiabaticity parameter. Reflection coefficient was measured as a function of the beam current (particle density) also.
A simple plasma gun was used to study the nonadiabatic effects on plasma during a single reflection. The plasma parameters were measured using conventional diagnostics. To measure the reflection coefficient, the collector near the midplane was not used and instead the transmission efficiency was measured from which the reflectivity of the mirror was calculated assuming that the plasma loss was only through the mirror throats. This was to avoid the perturbations on the plasma by the collector at the midplane during its travel in the system. During the reflection, floating potential was measured around the mirror point on either side of it along the axis.

From all the observations made on the reflection coefficient for the plasma as well as the electron beam, we can conclude that the nonadiabatic mirror can also become as effective as an adiabatic mirror for electron beams, when the beam density goes above some critical value. From the plasma floating potential measurements near the mirror point, we see the formation of strong electrostatic potential at steep magnetic field gradients. Then the normal reflection is enhanced by additional electrostatic reflection due to the potential hill for the electrons, thus increasing the effective reflection coefficient; making the nonadiabatic mirror as effective in plasma confinement as the conventional mirrors.
5.2. Results from the Confinement Experiment

The second part of the work (chapter IV) deals with the study of nonadiabatic particle leakage from an adiabatic mirror. The leakage current through the mirror throat was measured as a function of time for different values of particle energy and different magnetic field configurations. The semi-log plot of the decay current as a function of time could not be approximated by single exponential decay. Therefore, numerical analysis for a least square fit was carried out. In most of the cases the experimental results were best approximated by two exponential decay times. Fractional amplitudes of the signal corresponding to the two decay times were also estimated. From \( \ln(\frac{C_n}{n}) \) vs \( B \) curves, it was observed that the variations were linear and the ratio of the slope for the second life time to the first life time was between 1.8 to 2.3. This could be considered in good agreement with the theoretical prediction of 2. Table II shows the slope variation as a function of particle energy and magnetic field scale length. The slope values decreased as the energy of particles increased. Whereas, the slope value increased with an increase in the magnetic field scale length. This behaviour is in qualitative agreement with the theoretical predictions. However, for consistency check, the pitch angle was calculated using the experimental slope values. The pitch angle variations for the two different cases were between 32°21'49"-32°26'48" and 34°18'22"-34°21'12".
This shows that as the pitch angle is shifted away from the adiabatic loss cone, the variations in calculated pitch angle decrease. For better quantitative agreement, the experiment should be performed for larger pitch angles. But without major modifications in the experimental system, this is not possible as mentioned earlier.

Effective bounce time, $T_{\text{eff}}$, was experimentally obtained. This represented an "effective bounce period" such that the probability of escape per bounce was given by equation (4.3.2). The number of adiabatic bounce periods $T_b$ in a $T_{\text{eff}}$ was also calculated. This represented the number of bounces that a particle would make on the average before it escaped with a probability $P_n$. However, theoretical estimation of this number has not yet been done.

The effect of the shape of the magnetic field profile on the slope values was also investigated. Thus, the conclusions that can be made from this experimental work are: 1) The leakage of particles of a given energy $E$ and initial value of the action invariant $\mu$ is characterised by more than one lifetime. 2) The two lifetimes are found to be exponential functions of confining magnetic fields, with the ratio of the exponents lying in the range of 1.8 to 2.3, which can be considered to be in good agreement with the theoretical value of 2. 3) The values of exponents are found to vary with
energy $E$ and magnetic field scale length $L^{-1}$, which is in qualitative agreement with theory. This agreement becomes more quantitative for larger values of the pitch angle. 4) Amplitude corresponding to life time $\tau_1$, is found to increase with the magnetic field while that corresponding to $\tau_2$ decreases until it becomes vanishingly small for sufficiently large magnetic fields.

5.3 Future Experimental Programme.

The present work described in this thesis can be considered as the basis for more experimental studies to have a better and complete understanding of the phenomenon. Continuing in the same line of experimental work, one can do the experiment at larger pitch angles. Since, it was not possible to attain higher pitch angle in the present set up, some modifications in the source region would be necessary. With the required modifications one would be able to investigate the slopes corresponding to different life times at higher pitch angles and seek for better quantitative comparison with the theory.

It can be noted that the theory mentions multiple life times for particles with same energy and initial value of the magnetic moment. It would be highly interesting, therefore, to see if there exists at least a third life time. For this, one has to increase the signal amplitude to avoid contamination of the data due to digitisation error.
From the observations made in subsection 4.3.5, it is seen that any change in the shape of the magnetic field configuration near the magnetic mirror changed the slope values for the two observed life times. To have a thorough understanding of this behaviour, experiments can be conducted in different field configurations of different shapes, keeping the field scale length constant to have a better comparison among the slope values for different field configurations of different shapes. With all these further experimentations, one would be able to study many more interesting aspects of the problem discussed in this thesis.