A STUDY OF THE MONTE CARLO RADIATION TRANSPORT CALCULATIONS

SYNOPSIS

The work presented in the thesis is carried out by the candidate to investigate the use of Monte Carlo procedures in radiation transport problems. First, a hybrid method for solving the integral form of the Boltzman transport equation is studied where integrations over the kernels are carried out partly by analytic and partly by Monte Carlo methods. Second, a systematic study of some of the variance reducing techniques, available for Monte Carlo radiation transport calculations, is made. The investigation is made with respect to variance, computation time and efficiency associated with each of the techniques.

The thesis is divided into four Chapters.

CHAPTER I: INTRODUCTION

In this Chapter an introduction to the radiation transport problem is given with the help of integrodifferential and integral forms of the Boltzman transport equation. The integral forms of the corresponding adjoint equations are also derived. A description of the Monte Carlo random walk and its simulation in solving the transport problem is given. The importance sampling technique and biasing with
importance functions are described. Work done by earlier workers is critically reviewed. The scope and objects of the present work is given.

CHAPTER II: A SEMIANALYTIC MONTE CARLO SOLUTION OF THE TRANSPORT EQUATION

An iterative scheme is developed for solving the integral transport equation in one dimension. Space, energy and direction are divided in a number of mesh points such that each material(region) boundary coincides with a space mesh point and at least one is located within a given medium if the medium happens to be thicker than one source mean free path. The energy mesh points are determined by the nature of the scattering law. The direction mesh points are placed at uniform intervals. The integration over space is done by analytic procedures. This helps to mitigate the large variances associated with Monte Carlo results at deep penetration. The energy and direction after scattering are sampled randomly from the collision kernel. Random sampling from the collision kernel enables the use of point energy cross-section and angular distribution data and avoids the need for group to group transfer matrix data. This also allows easy updating of or deliberately changing individual cross section values and the use of any arbitrary energy group structure.

The method can be applied for heterogeneous slabs with a space mesh up to four source mean free paths apart.
A set of coupled integral equations are derived to provide the expected statistical error in any biased Monte Carlo transport calculation. The present treatment takes account of situations where more than one particle emerge from a collision with distribution in the statistical weights. These formulations are used to obtain the variance and number of collisions per history in a few Monte Carlo schemes using exponential transform. The schemes considered include procedures such as splitting, weighting in lieu of absorption and next event estimation. Optimization of different procedures as well as their comparative merits are discussed for a sample one group problem in the following cases:

(i) Biasing by exponential importance function and carrying weights,

(ii) Exponential transform with splitting,

(iii) Exponential transform with next event estimator,

(iv) A variant on the exponential transform as suggested by Chilton.
CHAPTER IV: APPLICATION IN MULTIGROUP PROBLEMS

The formulations derived in Chapter III are applied to solve typical multigroup problems. The two specific problems studied are:

(i) passage of neutrons through a slab of hydrogen,

(ii) passage of gammas through a slab of water

The integral equations obtained for the first and second moment are solved using iterative techniques. Each of the equations is written in the form of a set of coupled integral equations separating the space and energy-angle transmissions.

The optimal values of variance and efficiency are obtained for a number of incident energies and slab thicknesses.