Monte Carlo simulation of radiation transport is the most accurate means of computing dose distributions, but, due mainly to inordinately long computation times, it has hither-to-fore been impractical for all but investigational purposes. However, because of the continuing advancements in computer technology, algorithms, and variance reduction techniques, we are rapidly approaching a time when we can begin exploiting the benefits of Monte Carlo methodology routinely. The main benefit of Monte Carlo techniques is, of course, the universal dosimetric accuracy for all modalities (photons electrons, and brachytherapy) and for all anatomic and delivery system geometries. The use of Monte Carlo methodology would obviate the need for the endless effort expended in modification, parameterization and refinement of empirical and semi-empirical models for correcting for inhomogeneities, surface irregularities, and scattering from treatment machine components and field shaping devices. Monte Carlo-based treatment planning would lead to greater consistency of treatments in different institutions employing the same technique, which could be especially helpful for multi-institutional clinical trials. Its use should make dose response data more dependable. In addition, Monte Carlo simulations would allow accurate and detailed estimation of quantities that are difficult and sometimes virtually impossible to measure. Furthermore, the labor and arduousness of commissioning Monte Carlo-based treatment planning systems would be significantly reduced. For efficiency, Monte Carlo simulations for dose calculations are divided into two stages: (1) a patient independent stage above the jaws, which has to be simulated only once, and (2) a patient dependent stage including the radiation transport through jaws, wedges, blocks and MLCs (dynamic or static). Although Monte Carlo calculations may be applied in the near future for routine patient care, there is still a considerable amount of work to be done. For instance, one needs to establish the accuracy and precision requirements of the results of simulation of the first stage, i.e., the contents of the “phase space description” (PSD) of the machine so that the impact on the accuracy of dose distribution calculations is negligible. Often complete and accurate information needed to compute PSDs is not available. Therefore, some justifiable empirical means of accounting for such less than exact information have to be developed. Using a PSD, one must define a “source distribution” from which particles can be efficiently sampled without loss of accuracy in computed dose. In regard to the second stage, a number of issues need to addressed. These include estimation of atomic composition and densities from 3D images, schemes of defining the geometry of patient specific beam shaping devices, developing techniques for special applications such as IMRT, and strategies to reduce statistical uncertainty to acceptable levels without compromising accuracy.

Educational Objectives: (1) Description of fundamental principles of Monte Carlo techniques as applied to radiation therapy. (2) Demonstration of the potential advantages of Monte Carlo techniques. (3) Illustrations of the further work to be done to make Monte Carlo more efficient and effective.