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Calculations of Medical Physics Radiation Dosimetry Systems Using MCNP Version 5

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Introduction

MCNP™ Version 5 has just been released to the Radiation Shielding Information Computational Center.[1,2] The code has new features that greatly facilitate the simulation of complex radiation transport problems, including those in Medical and Health Physics.[3] In this work, two of these features, Doppler energy broadening of low energy photons, and pulse height tally variance reduction for photons, were used in the calculations of seven radiation dosimetry and detector problems. These problems are a part of an international intercomparison of radition dosimetry computer codes, sponsored by the European Commission committee on the quality assurance of computational tools in radiation dosimetry.[4] Our results were submitted to the committee, which will perform the inter-code comparison and publish the results independently. The focus of this work is to exercise the new version of the code in an international benchmark effort, and to highlight the new features of the code relevant to these problems.

Description of the Benchmark Problems

Problem 1 studied the near-field angular anisotropy and dose distribution from a high dose rate Ir-192 Brachytherapy source in a surrounding water phantom. The Ir-192 source was modeled as a core capsule with radius 0.0325 cm and length of 0.36 cm. Enclosing the Ir-192 source was a stainless steel capsule attached to a woven steel cable. The Ir-192 core, steel encapsulation, and woven steel cable are modeled within a 5 cm sphere of water, which was considered to be near field. The sphere was then divided into wedges with angles of 10 degrees from 0 to 180 to determine anisotropy factors, while cylinders with radii increasing by 1 cm increments where used to determine radial dose depth.

Problem 2 looked at both the radial and axial dose in a vessel wall from an intravascular brachytherapy P-32 source contained in a polyethylene matrix. The source is cylindrical with a diameter of 0.24 mm and length of 27 mm. It is encapsulated within NiTi with a 1 mm long Tungsten cylindrical marker (0.24 mm diameter). The radial dose is measured in a water phantom by concentric cylinders while axial dose is measured in disks. The addition of a plaque on the artery walls and its affect upon the radial and axial dose is also modeled.

Problem 3 investigates the response of a four-element TLD-albedo personal dosimeter from neutrons and/or photons. Elements 1 and 2 are bare ^{6}LiF and ^{7}LiF detectors, respectively, with boron-loaded plastic behind them. Elements 3 and 4 are covered with a 1 mm thick aluminum disc plus 4 mm of

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boron-loaded plastic. The photon response is determined by measuring dose to the TLD elements while neutron response is measured by counting $^{6}Li(n,t)^{4}He$ capture reactions. The fraction of neutron and photon response due to backscatter from a water phantom is also determined.

Problem 4 models air kerma backscatter profiles for a 150 and 200 kVp X-ray tube upon a 30 cm x 30 cm x 15 cm water phantom. The air kerma backscatter is determined at the center of the front face of an ISO slab phantom.

Problem 5 involves neutron field perturbation measurements at two points behind a shadow cone. The shadow cone consists of iron and polyethylene layers designed to suppress direct contributions to the detector from the source. The distribution of neutron fluence in energy at the two positions is determined as well as the contribution to the neutron spectral fluence from the different directions. The contributions to the energy fluence from air and walls are also differentiated.

Problem 6 studies detector peak efficiencies and pulse height distributions for a germanium detector. The detector includes dead layers and is partially imbedded in an aluminum holder.

Problem 7 models a polyethylene sphere with a spherical proportional He-3 counter as a neutron measuring device. Uncertainties in the position of the instrument and the radioactive source are examined to determine the constancy of the calibration.

Results

The key results obtained included radial and axial dose profiles, energy deposition tallies including the pulse height tallies. Angular flux distributions were obtained for many of the systems. Some of the new features of the code that were tested are the Doppler energy broadening of low energy photons and the usage of variance reduction with pulse height tallies for photons. For many of the problems, sensitivity studies were carried out to examine the effects of different cross section libraries and tally specifications.

References

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