Computer Code Abstract

SPHERE

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1. Program Identification: SPHERE, a spherical-geometry, multimaterial electron/photon Monte Carlo transport code.[1]

2. Description of Physical Problem Solved: SPHERE describes the generation and transport of the electron/photon cascade from several MeV down to 1.0 keV for electrons and to 10.0 keV for photons, respectively, in spherically symmetric multimaterial geometries. Source particles may be either electrons or photons; monoenergetic or source spectra are allowed; and source angular distributions may be monodirectional, cosine law, or isotropic. The most important output data are (a) charge and energy deposition profiles, (b) integral energy and number escape coefficients for both electrons and photons, and (c) escape coefficients for electrons and photons that are differential in energy, in angle, and in both energy and angle.

3. Method of Solution: The SPHERE code combines the condensed-history electron Monte Carlo code[2] with the conventional single-scattering photon Monte Carlo code. The electron transport includes energy-loss straggling, elastic scattering, and the production of knock-on electrons, continuous bremsstrahlung, characteristic x rays, and annihilation radiation. Photon transport includes the photoelectric, Compton, and pair-production interactions, along with the production of the corresponding secondary particles. Electron cross sections and sampling distributions are obtained from DATAPAC-4 and LIBRARY TAPE 2 of the ETRAN Monte Carlo code system.[3] Photon cross sections are the analytical fits given by Biggs and Lighthill.[4] SPHERE is a user-oriented code in the sense that it was designed to provide both experimentalists and theorists with a method for the routine, but sophisticated, solution of basic transport problems. For example, as a consequence of automated subzoning and boundary-crossing logic, only ten input cards are required to obtain two-dimensional charge and energy deposition profiles in a single material for a monoenergetic source. On the other hand, the completeness with which SPHERE describes the radiation transport and the flexibility of its construction make it possible for the user to extend its capabilities significantly through relatively simple updates. Examples of these extended capabilities are (a) energy spectrum and spatial distribution of the internal flux, (b) forcing of photon collision, and (c) biasing of bremsstrahlung and characteristic x-ray production. Every output quantity is followed by the best estimate of its statistical standard error. By storing the five largest cross-section arrays in extended core storage (ECS) instead of central memory, the central memory requirement has been reduced more than 50 000 decimal locations. Further reductions are possible at little or no increase in running time whenever such fast peripheral access is available.

4. Related Material: SPHERE contains much of the same logic found in the TIGER code[5] and ETRAN code,[3] which are used for one-dimensional slab geometries, and the CYLTRAN code,[6] which is used for two-dimensional cylindrical geometries. Comments, suggestions, and/or consultation are welcomed by the authors.

5. Restrictions: The problem configuration is limited to no more than 50 material or void zones. A problem may not involve more than five unique homogeneous materials, each of which contains no more than 20 elements. The method is more accurate at higher energies, with a less rigorous description of the particle cascade at energies where the atomic shell structure of the transport media becomes important. The only shell effects considered are ionization of, fluorescence from, and Auger emission from the K shell of the highest-atomic-number element in each material.

6. Computer: CDC 6600 (also compatible with CDC 7600 with minor modifications).

7. Running Time: So many parameters affect the problem run time that it is not possible to estimate a "typical" machine time. However, run times do vary almost linearly with the number of histories. The average time per history required for the calculation of the charge and energy deposition profiles shown in Figs. 5 and 6 of Ref. 1 was ~0.025 s.

8. Programming Languages: The code is written in FORTRAN IV. A major effort was made to remove nonstandard and installation-dependent usages.

9. Operating System: The code runs under the SCOPE 3.3 system with the FTN (OPT = 2) compiler.

10. Machine Requirements: Four input/output files (two input cross-section files and two scratch files) and two system input/output files are required. The central memory storage requirement is 156 000 (octal) words. In addition, 245 000 (octal) words of

ECS are required. Data are transmitted to and from ECS in blocks of variable size, so that with some program modifications, disk, drum, or tape storage can be substituted for ECS.

11. Material Available: Source deck, cross-section files, test problems, results of executed test problems, and the reference document[1] are available from the Oak Ridge Radiation Shielding Information Center.

12. *Acknowledgment:* This work was supported by the U.S. Department of Energy.

13. *References:*

[1]J. A. HALBLEIB, Sr., "SPHERE: A Spherical-Geometry Multimaterial Electron/Photon Monte Carlo Transport Code," SAND77-0832, Sandia Laboratories (1977).

[2]M. J. BERGER, "Monte Carlo Calculation of the Penetration and Diffusion of Fast Charged Particles," *Methods in Computational Physics*, Vol. 1, Academic Press, Inc., New York (1963).

[3]M. J. BERGER and S. M. SELTZER, "ETRAN Monte Carlo Code System for Electron and Photon Transport Through Extended Media," CCC-107, Radiation Shielding Information Center, Computer Code Collection, Oak Ridge National Laboratory (1968).

[4]F. BIGGS and R. LIGHTHILL, "Analytical Approximations for X-Ray Cross Sections II," SC-RR-71 0507, Sandia Laboratories (1971); also, F. BIGGS and R. LIGHTHILL, "Analytical Approximations for Total Pair-Production Cross Sections," SC-RR-68-619, Sandia Laboratories (1968).

[5]J. A. HALBLEIB, Sr. and W. H. VANDEVENDER, *Nucl. Sci. Eng.*, **57**, 94 (1975).

[6]J. A. HALBLEIB, Sr. and W. H. VANDEVENDER, *Nucl. Sci. Eng.*, **61**, 288 (1976).