NERS 590 – Monte Carlo Software Design
Winter 2017
Homework 3
Due at noon on Apr. 14, 2017

In this homework set, you will extend your 3-D slab Monte Carlo transport code from homework 2 to support continuous-energy physics having cross sections with a simple $a + b/\sqrt{E}$ energy dependence. Your final code should, as before be in C++, be able to solve the provided problem (#6) and problems 1-5 from homework 2.

A random number generator will be provided to you that you should use. Do not use the intrinsic C rand() function as it, depending upon the compiler implementation, may have a very short period and not be acceptable for scientific computing.

You should parse XML input in this assignment to receive full credit. Input files should be provided with the description. As before, internally, your code should be structured such that there is an initialization portion that handles problem setup and an execution phase that is coded generically (i.e., no references to problem definitions in this portion) to handle any problems within the scope. Your code should also build via a Makefile and be accessible from a Github repository.

To summarize, the design requirements are:

- 3-D geometry with energy-dependent transport,
- Multiple regions and constituent isotopes,
- Support for surfaces including planes, spheres, axis-aligned cylinders, and axis-aligned cones,
- Vacuum and reflecting boundary conditions,
- Isotropic and anisotropic scattering (see problems 1, 4, and 6), and energy-dependent stationary target-scattering (problem 6),
- Fission with a multiplicity distribution (see problem 3),
- Fixed sources with prescribed distributions in space and direction (see problems),
- Estimators for leakage (problems 1 and 2), support for counting the number of neutrons leaked out per history (problem 3), and reaction rate fluxes using track-length estimators (problems 4-6)
- Importance splitting for variance reduction (problem 5),
- Compilation with a Makefile,
- Accessible from a Github repository,
- XML user input to easily run any of the test problems.

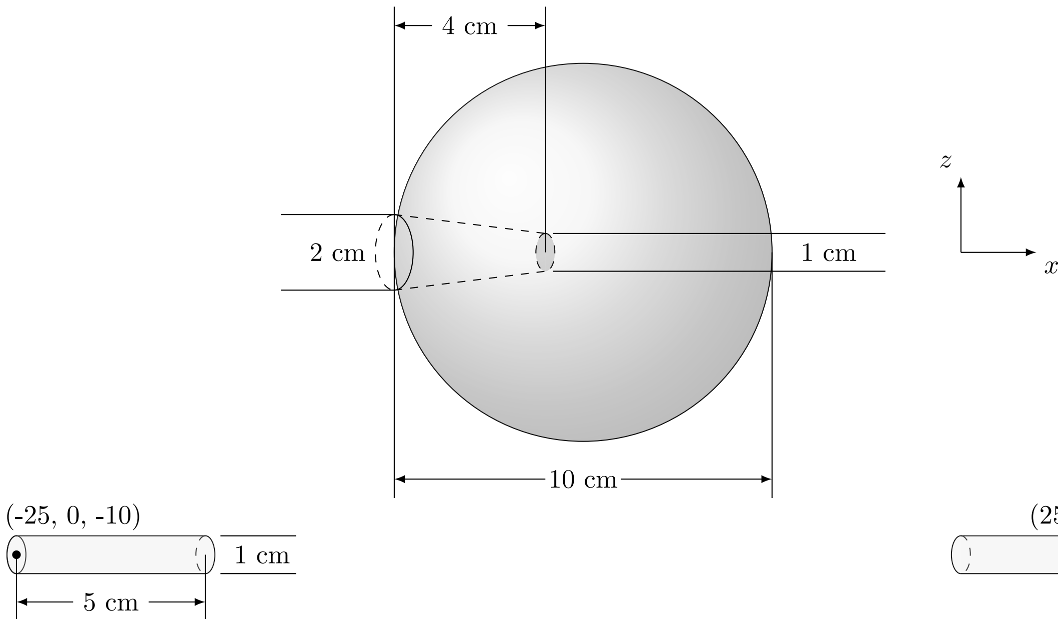
You may work on this assignment in a group of up to 3 people, and I am happy to provide reference solutions and work with you to develop your code. Members of your group must still write all lines of code with the exception of the provided random number generator and other source codes I provide in class.

Your code should be capable of running all problems 1-6. Turn in a document reporting the results of the given test problems and quantify their statistical uncertainties. Your code should be available on Github and include a Makefile.

The grading will be done as follows:

Item	Points
Report	50
Code clarity and style	50
Results: problems 1-5	30
Results: problem 6	40
XML input	20
Github checkout and Makefile	10

6. Consider a sphere centered at the origin with a truncated conic hole bored into it as depicted in the figure below. (Note that distances that the detectors are away from the sphere are not drawn to scale.)



A monoenergetic disk source of neutrons is placed at the inner surface of the truncated cone. The spatial distribution of the particles is uniform in area along the disk, but the angular distribution (polar cosine) is forward peaked with a probability density function

$$p(\mu) = \frac{1}{6}\left[1 + (\mu + 1)^3\right]$$

with the axis (north pole) oriented along the positive x direction; the azimuthal angle is uniform. All neutrons start at time $t = 0$ with an energy of 1.0 MeV.

The sphere has an atomic mass ratio of defined in each problem part, an atomic density of 0.1 $\text{b}^{-1}\cdot\text{cm}^{-1}$, and energy-dependent microscopic cross sections $\sigma_c = 0.1/\sqrt{E}$ b, and constant $\sigma_s = 2.4$ b (E is in MeV). Scattering is linearly anisotropic in the center-of-mass frame with an energy-independent (center-of-mass) scattering cosine $\overline{\mu}_{cm} = 0.2$.

Two detectors cylinders with circular-base diameter of 1 cm and height of 5 cm are placed outside the sphere. The first is oriented along the x direction with a base located at $(-25, 0, -10)$ and the second is oriented in the x direction with its base at $(25, 0, -10)$. The detectors are pointing toward the sphere. The detector material has an atomic density of 0.1 $\text{b}^{-1}\cdot\text{cm}^{-1}$, $\sigma_s = 1+0.5/\sqrt{E}$ b, and isotropic scattering in the center-of-mass frame with $A = 1$. Each detector measures the number of scattering reactions with time binning ($t = 0$ is the time particles are emitted from the source). Each time bin has an interval width of 5 nanoseconds and the detector measures up until 100 nanoseconds. Use a track-length estimator. Scattering may be treated assuming a stationary target, but you should consider implementing a time cutoff to ensure the particle energy does not get arbitrarily small in this case.

From the results your code generates, produce a plot with the time-binned detector response (in semilog scale and with error bars) for each detector. Each plot should have three curves, one for each of the following atomic mass ratios: (a) deuterium ($A = 2$), (b) lithium-6 ($A = 6$), and (c) carbon ($A = 12$). Run each case for 10^8 histories. Each simulation should calculate results for both detector responses, i.e., there should be one simulation for each value of A for three total simulations.