

22.54 Neutron Interactions and Applications (Spring 2002)

Problem Set No. 5

Due: March 14, 2002

1. Imagine you are writing a Monte Carlo program and you model a monoenergetic point source of 3.0 MeV neutrons located in the center of a large volume of CH₂ ($\rho = 0.92 \text{ g cm}^{-3}$). At this energy C has an elastic scattering cross section of 1.14 b while H has an elastic scattering cross section of 2.23 b (assume no other processes are involved). The point source is located at an x, y, z position of 5, 5, 5.

Now assume that the random number generator used by your Monte Carlo code generates the following as its first ten random numbers: .32, .67, .16, .02, .07, .85, .17, .96, .54, .71.

- (a) Calculate the position of the first interaction of the first history and the nuclide the neutron will interact with. Show your work.
 - (b) Assume a scattering angle and determine the energy given to the scattering nuclide.
2. Print out the total interaction cross section, the elastic scattering cross section, and the total absorption cross-sections for the following nuclides/materials:
Carbon, Hydrogen, light water, heavy water, ¹⁰B, and ¹¹³Cd.

Construct an MCNP Input File:

Place a 3 MeV point source of neutrons at the origin [sdef erg 3] and embed it in a sphere of CH₂ of radius R (you'll be choosing the value(s) of R). Surround your sphere with a spherical detector, that is, a tally placed at some distance, d, away from the edge of the sphere of CH₂, in air. Add a tally energy card to obtain the energy spectrum of detected neutrons. Your tally cards will look something like this:

F2:n S (where S is the surface number)
e2 E₁, E₂, E₁, E₂, E₃ ... E_k

This will give a surface flux tally in each energy bin (from 0 to E₁, E₁ to E₂, etc) and one for the total.

- (a) For one value of R, compare the total number of neutrons detected in your tally to the number predicted by the exponential attenuation law as presented on p. 20 of the Duderstadt and Hamilton handout. [Use the value of the total interaction cross-section you calculated for question 1.] Discuss the physical reason for any differences. Explain why the approach used to determine distance to first interaction in question 1 is valid.
- (b) For three significantly different values of R, plot the resultant energy distribution detected in your tally. Be sure to include error bars on the plots. Comment on what is happening both to the spectrum, and to the relative uncertainty. [Try to keep N (ie nps) roughly constant here.]

- (c) Make your tally area much more ‘physically realistic’ by giving it a much smaller area. You can either do this by constructing (in the geometry specification portion of the input file) a small, 20 cm diameter, right-circular cylindrical air-filled detector placed at R plus distance d, or you can simply ‘segment’ your existing tally surface. To do this, add a cylindrical surface with radius 10 cm to your list of surface cards. [You don’t need to use this surface in your geometry.] Then, add the following card to your tally

FS2 -20 (where 20 is the number of the cylindrical surface)

which instructs the code to ‘segment’ the tally into what is detected, on the surface, but inside the cylinder (-20), and what is detected, on the surface, outside the cylinder (+20).

Comment on the values of x_i (mean tally value), R (relative error) and FOM in terms of how they compare to those values obtained as part of (a) or (b) above.

- (d) Add several percent of a nuclide having a high neutron absorption cross-section to the CH_2 . Now, compare N for a few different R to the values of N predicted based on the exponential attenuation predictions (as you did for part (a)). Comment on the comparison and why the comparison might lead to different results than those obtained in part (a).
- (e) Finally, for a fairly large value of R, and still using the compound mixture (of CH_2 and neutron absorber) you made for part (d), incorporate importance sampling in your geometry. For example, separate your sphere into concentric spheres (separate cells) with importances that increase as the radius increases (eg 1, 2, 4, 8, 16). Compare values of tally mean, R, T (computer time) and FOM with those obtained in part (d) for a similar R. Discuss.