ENGY.4340 Nuclear Reactor Theory

Fall 2016

HW #3: Neutron Diffusion in a Moderating Medium

Problem 1 Neutron Diffusion in a Moderating Medium (Spherical Geometry) (10 points)

Note that 1 ft of moderating material is approximately 30 cm. Using the Matlab *spheremm_gui* program we want to explore neutron diffusion in two different moderating materials, water and graphite, in spherical geometry. For consistency, select R = 30 cm and generate/record the flux plots and balance table information for these two cases (explore both the linear and logarithmic plot scales). Make sure you understand what this code is doing...

Based on the data generated, answer the following questions:

- 1. What is the appropriate thermal diffusion length for water? How about graphite? What is the physical interpretation of the diffusion length, L? Based on this, what can you say about the difference in thermal neutron diffusion in water versus graphite?
- 2. Using the *spheremm_gui* simulation tool, find a value of R where leakage accounts for about 25% of the overall neutron balance for the case of the infinite media problem (i.e. 25% of the neutrons emitted into the infinite sphere pass the r = R location). Do this for both water and graphite. Now convert these values into number of diffusion lengths by dividing by the appropriate value of L (i.e. the number of diffusion lengths from the source is simply distance/diffusion length). Compare this result for the water and graphite media for the case where the leakage is 25% of the overall neutron balance. Did you expect this result? Explain...

Problems 2 Validating the Neutron Balance (Spherical Geometry) (10 points)

The flux in an infinite moderating medium with an isotropic point source with strength Q at the origin of the system (i.e. at r = 0) was formally derived in the Lecture Notes and is given by

$$\phi(r) = \frac{Q}{4\pi D} \frac{1}{r} e^{-r/L}$$

Formally demonstrate that the neutron balance in a region defined by $R/2 \le r \le R$ is satisfied -that is, show that **leakage** + **absorption** = **source** within the region of interest, where R is simply some given radius. Show all your work...

Hint: In doing this formal balance, note that, for the case of a point source at r = 0, there is no source in the spherical shell region between R/2 and R.

Problems 3 Finite Bare Homogeneous Sphere with a Uniform Source (15 points)

Consider a *finite bare sphere* of moderator of radius R that contains a *uniformly distributed source* emitting Q neutrons/cm³-sec.

- 1. Formally derive a result for $\phi(r)$ for this system assuming 1-group theory, where r is measured from the center of the finite bare sphere.
- 2. What is the neutron leakage out of the bare sphere? What is the absorption rate within the sphere (from $0 \le r \le R$)? Does this make physical sense? Explain...

Problem 4 Two-Region Sphere with a Uniform Source in the Interior Region (15 points)

Consider a *two-region problem* that involves concentric spheres. The inner sphere has a radius R and it has a *uniformly distributed source* emitting Q neutrons/cm³-sec. Surrounding the inner moderating medium is a very large region filled with a second moderator (this can be considered as an infinite region). There is no external neutron source in the outer region. For consistency, use the subscript 1 to denote the material properties for the inner region, and subscript 2 to represent the outer (infinite) region.

Assuming 1-group theory, **formally develop** the *general solutions* for the flux profile in both regions. Then, using appropriate boundary and interface conditions as needed, develop the *unique solution* for $\phi(r)$ throughout both moderating regions. Be systematic in your development.