NE 250 Fall 2017
Homework #5 Due November 17th, 2017

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1. (10 points) Answer the following questions as true or false. Provide a one sentence justification for your answer.

   a. For reactors, we often use the α-eigenvalue formulation rather than the k-eigenvalue formulation for criticality calculations.

   b. On a surface $\vec{r}_s$ with fixed (not necessarily vacuum) boundary conditions, the *un*collided flux *must* satisfy $\psi_0(\vec{r}_s, \hat{\Omega}, E) = 0$, $\hat{\Omega} \cdot \hat{n} < 0$.

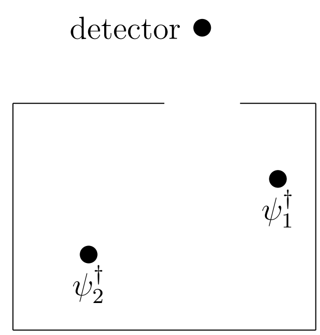
   c. On a surface $\vec{r}_s$ with fixed (not necessarily vacuum) boundary conditions, the *once*-collided flux *must* satisfy $\psi_1(\vec{r}_s, \hat{\Omega}, E) = 0$, $\hat{\Omega} \cdot \hat{n} < 0$.

   d. The streaming operator in the transport equation is self-adjoint.

   e. The source for the adjoint problem is always proportional to the source for the forward problem.

   f. [okay, this one isn't true or false] Shielding material (not shown in the figure) is placed in a room so as to reduce the detector reading outside the door. Solution of the adjoint TE for the room, with $V_d \Sigma_d(E) \delta(\vec{r} - \vec{r}_d)$ as the adjoint source, indicates that $\psi_2^\dagger < \psi_1^\dagger$.

   Would you place a container of radioactive waste at point one or point two? Why?



2. (20 points) Find the adjoint equation corresponding to

$$\left[\hat{\Omega} \cdot \nabla + \Sigma(\vec{r}, E) + \frac{\alpha}{v}\right] \psi(\vec{r}, \hat{\Omega}, E) = \int dE' \int d\hat{\Omega}' \, \Sigma_s(\vec{r}, E' \to E, \hat{\Omega}' \cdot \hat{\Omega}) \psi(\vec{r}, \hat{\Omega}' E') + \frac{\chi(E)}{4\pi} \int dE' \, \nu\Sigma_f(\vec{r}, E') \int d\hat{\Omega}' \, \psi(\vec{r}, \hat{\Omega}', E')$$

and prove that $\alpha^\dagger = \alpha$.

Find the first-order perturbation expression relating $\delta\alpha$ to ψ_0 and $\psi_0^\dagger$, the unperturbed flux and its adjoint, respectively.

Comment on why one would choose the α-eigenvalue perturbation equations compared to the k-eigenvalue perturbation equations.

3. (10 points) Suppose that, instead of detector response given by $R = V_d \int dE \Sigma_d(E)\phi(\vec{r}_d, E)$, we want to calculate the current:

$$J_n^+(\vec{r}_d, E) = \int_{\hat{\Omega}\cdot\hat{n}>0} d\hat{\Omega}\, \hat{\Omega}\cdot\hat{n}\, \psi(\vec{r}_d, \hat{\Omega}, E)\ , \quad \vec{r}_d \in \Gamma\ ,$$

the number of particles leaving V with boundary Γ at $\vec{r}_d$ in per cm^2 per unit energy. Derive an expression for $J_n^+(\vec{r}_d, E)$ in terms of the adjoint flux, $\psi^\dagger$

   a. when the particles originate in V from some q_{ex}, and
   b. when the particles enter V across Γ as a known flux given by $\psi(\vec{r}, \hat{\Omega}, E) = \tilde{\Psi}(\vec{r}, \hat{\Omega}, E)$ with $\vec{r} \in \Gamma$ and $\hat{\Omega}\cdot\hat{n} < 0$.

4. (10 points) Estimate the fast group constants characterizing H_2O if the fast group is taken from $E_1 = 1\, eV$ to $E_0 = 10\, MeV$ and the neutron energy spectrum over this group is taken as $\phi(E) \simeq 1/E$.

5. (10 points) Determine the neutron flux $\phi(E)$ resulting from a mono-energetic source at energy E_0 in an infinite hydrogenous medium if the scattering cross section is taken to be constant and the absorption cross section is inversely proportional to the neutron speed.

6. (20 points) Derive

$$\begin{aligned}[\hat{\Omega}\cdot\nabla + \Sigma_{tg}(\vec{r})]\psi_g(\vec{r}, \hat{\Omega}) = &\sum_{g'=1}^{G} \int_{4\pi} d\hat{\Omega}'\, \Sigma_{s,gg'}(\vec{r}, \hat{\Omega}'\cdot\hat{\Omega})\psi_{g'}(\vec{r}, \hat{\Omega}') \\ &+ \frac{\chi_g}{4\pi}\sum_{g'=1}^{G} \nu\Sigma_{fg'}(\vec{r})\phi_{g'}(\vec{r}) + q_g(\vec{r}, \hat{\Omega})\end{aligned}$$

without assuming $\psi(\vec{r}, \hat{\Omega}, E) \approx f(E)\psi)g(\vec{r}, \hat{\Omega})$. Use instead the assumption that all of the cross sections are piecewise constants, changing values only at E_g.

7. (10 points) Answer the following short answer questions. If true or false, provide a one sentence justification for your answer.

   a. True or False: using $\hat{\Omega}\cdot\hat{\Omega}'$ rather than $\hat{\Omega}' \to \hat{\Omega}$ in the scattering cross section implies azimuthal symmetry.
   b. What is the main challenge associated with the first way that we derived the multi-group equations?

c. For the more complex multigroup derivation, what is the consistent P_N approximation and how does that compare to the extended transport approximation?

d. List and briefly discuss three major concerns you might have about being able to accurately characterize uncertainties associated with nuclear data.

e. List three evaluated nuclear data sets managed by other countries.