NERS 561
Winter 2023

Assignment #9

Due April 3

1. [40] You are asked to write a computer program to solve the one-dimensional, one-group diffusion equation with space-dependent diffusion coefficient and cross sections:

$$-\frac{d}{dx}D(x)\frac{d}{dx}\phi(x) + \Sigma_a(x)\phi(x) = \frac{1}{k_{eff}}\nu\Sigma_f(x)\phi(x), \quad x \in [0, H] \tag{1}$$

   The problem domain H is divided into M equal-sized regions each of which has a single composition assigned. A "uniform" mesh size is still assumed with the following user-specified input parameters:

   (a) Problem domain size (H) in centimeters

   (b) Left and right boundary conditions α_L and α_R

   (c) Number of regions (K)

   (d) Number of mesh intervals (M) in each region (Note that the total number of mesh intervals can be obtained as N=K×M)

   (e) Number of different compositions in the problem (NCOMP)

   (f) Diffusion coefficient and cross sections for each composition
   $D(i), \quad \Sigma_a(i), \quad \nu\Sigma_f(i), \quad i = 1, \cdots, \text{NCOMP}$

   (g) Composition to region assignment
   $\text{MC}(k) \in \{1, 2, \cdots, \text{NCOMP}\}, \quad k = 1, \cdots, \text{M}$

   (h) Flux normalization condition: core average fission source density (AVGFS)

   (i) The convergence criteria for the multiplication factor (ε_k) and for the fission source in each mesh interval (ε_ψ)

   This program would be composed of (1) an input processing routine, (2) a routine to set up a system of discretized equations (i.e., the tridiagonal linear system), (3) routines to solve a tridiagonal linear system (a routine for LU factorization and another for forward elimination and backward substitution), (4) an eigenvalue solution routine and (5) an output processing routine. Write your program following the steps below. All floating-point variables should be declared as double precision.

   1) Write an input processing routine in a general form that reads all the parameters sequentially as specified above. The cross sections for each composition are given in one line. Refer to the following input deck for nine region, four composition problem:

```
180
0.5   0.5
9
5
4
1.150000E+00 2.780000E-02 2.850000E-02
1.100000E+00 2.680000E-02 1.840000E-02
```

```
1.150000E+00 2.790000E-02 2.830000E-02
6.500000E-01 2.270000E-02 0.000000E+00
4 1 2 1 2 3 2 1 4
1.0
1.0E-6  1.0E-5
```

2) Write a routine that sets up a tridiagonal linear system that incorporates the N mesh balance equations. Note that the fission source term on the right hand side is known from the previous outer iteration.
3) Write a routine that performs LU factorization of the tridiagonal linear system.
4) Write a routine that solves the tridiagonal linear system by forward elimination and backward substitution.
5) Write an outer-iteration routine that performs the power iteration. The outer-iteration routine sets up the RHS and then calls the linear system solution routine above. The new solution should be used to update the eigenvalue. The outer iteration should be terminated when both convergence criteria are met.
6) Write an output processing routine that provides the normalized fission source in each region as well as the fine-mesh flux distribution.

2. [20] Using your program, solve the problem given in Problem 1. Plot the fine mesh and region wise fission source distributions. Determine the eigenvalue and the dominance ratio.

3. [30] Wielandt shift method

   1) Double the domain size in Problem 2 by setting H=360 cm and obtain the solution and dominance ratio.
   2) Modify the outer iteration by implementing the Wielandt shift method. Add an input line to specify the outer iteration step to start the Wielandt shift. Execute problem 1) by starting the Wielandt shift at the outer iteration 2, 5, and 10, and then access the performance of Wielandt shift.