Reactor Numerical Analysis and Design

2006 년 2 학기

Final Examination

Dec. 8, 2006

1. Give the rationale for the following arguments as concisely as possible. (20 points)
   a. The use of the ordinary FDM is impractical in reactor analysis. Focus on the numerical properties as well as the computing requirements.
   b. The transverse integrated nodal method which involves converting one 3-D partial differential equation into three 1-D equations coupled through transverse leakage works fine with a low order approximation (e.g. 2-nd order) of the transverse leakage spatial variation.
   c. The analytic nodal method is not adequate for multigroup problems.
   d. A two-step procedure is necessary in the practical reactor analysis. Start explaining what's involved in each step.
   e. The Monte Carlo method has inherent inefficiency in enhancing the accuracy.

2. Answer the following questions regarding the solution of transverse integrated 1-D neutron diffusion equation in 2-D by the nodal expansion method (NEM) and by the analytic nodal method (ANM). (20 points)
   a. Give the basic solution form of the NEM for the x-direction. No need to give any specific polynomial definition.
   b. Suppose that four surface fluxes of the square node are given as the boundary condition. How many unknown expansion coefficients are there you need to determine? Consider two directions.
   c. You have four boundary conditions, but the number of your unknown coefficients are more than four. How would you define the other constraints to get a unique solution?
   d. Give the general solution form of the 2-group ANM. Indicate what are the unknown coefficients you need to determine.
   e. Suppose that you are solving a two-node problem with the node average flux boundary condition, namely two group fluxes values specified at both nodes. What other conditions you need to use to determine the ANM solution uniquely?

3. Answer the following regarding the analytic nodal method for two-group problems. (20 points)
   a. Show that the eigen-buckling (B^2) of a two group problem is given by the root of the following quadratic equation:

$$(D_1 B^2 + \Sigma_{r1} - \lambda \nu\Sigma_{f1})(D_2 B^2 + \Sigma_{r2}) - \lambda \nu\Sigma_{f2}\Sigma_{12} = 0 \qquad (1)$$

   b. Derive an expression for the infinite multiplication factor from the above equation noting that $k_\infty = \frac{1}{\lambda}$ in case of no leakage.

   c. Eq. (1) can be converted as follows using the above definition of k_∞:

$$\left(B^2\right)^2 + \left(\frac{\Sigma_{r1}}{D_1} + \frac{\Sigma_{r2}}{D_2} - \frac{\lambda \nu\Sigma_{f1}}{D_1}\right)B^2 + \left(1 - \frac{k_\infty}{k_{eff}}\right)\frac{\Sigma_{r1}}{D_1}\frac{\Sigma_{r2}}{D_2} = 0 \qquad (2)$$

   The coefficient of the second term is always positive since $\frac{\nu\Sigma_{f1}}{D_1}$ is much smaller than the other terms. What can you tell the sign of the two eigen-bucklings by examining Eq. (2)?

d. What is the consequence of the sign of the buckling on the flux shape?

4. Answer the following regarding the Monte Carlo method (30 Points)
   a. Show that the standard deviation of occurrences of a low probability (p) event per trial is given by $\sigma = \frac{\sqrt{p}}{\sqrt{N}}$ where N is the number of trials.
   b. Let the k_i be the eigenvalue estimate for Cycle i. If you have C estimates of k_i, and $\bar{k}$ is the average of those, what would be the expected standard deviation σ of $\bar{k}$? What is the significance of the expression $\bar{k} \pm \sigma$ being used to report the result?
   c. Draw a flow chart of Monte Carlo simulation of a particle migration by indicating concisely what should be done in each block.
   d. Compare the collision and track length estimator of the absorption rate for an energy group in a cell by starting from explaining how to obtain those.

5. Answer the following regarding simplified heat transfer solution. (10 points)
   a. Give the three equations needed to be solved for simplified heat transfer problem under the condition of a constant pressure, single phase, closed channel, heat conduction-convection problem.
   b. Derive the finite difference approximation (both spatial and temporal) of the heat conduction equation for an interior node, which should be second order accurate.

6. Describe the most interesting and important thing you learned from this course, that you think other students must also know. (Bonus points)