ENGINEERING PHYSICS 4D3/6D3

DAY CLASS — Dr. Wm. Garland

DURATION: 3 hours —

McMASTER UNIVERSITY FINAL EXAMINATION — December 11, 1991

Special Instructions:

1. Open Book. All calculators and reference material permitted.
2. Do all questions.
3. The values of each question is as indicated.
   TOTAL Value: 100 marks

THIS EXAMINATION PAPER INCLUDES 4 PAGES AND 8 QUESTIONS. YOU ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR INVIGILATOR.

---

1. [15 Marks Total]

   (5 marks)
   a) Boron is a common material used to shield against thermal neutrons. Estimate the thickness of boron required to attenuate an incident thermal neutron beam to 0.1 % of its intensity. Use $E_a = 103\ cm^{-1}$.

   (10 marks)
   b) Consider the case where 10^{10} neutrons / sec cross a unit area in the positive direction and 0.5×10^{10} neutrons / sec cross the same unit area in the negative direction. Compute the neutron flux and the neutron current.

2. [10 Marks Total]

   In nuclear reactors a newly-formed radioactive isotope A may be transformed into another isotope B by neutron absorption before it has had an opportunity to decay. Neutron absorption occurs at a rate proportional to the amount of isotope A present in the system. If the proportionality constant is denoted by c, and the rate of production (atoms of A / sec) is denoted by R (a constant), what is the number of atoms of isotope A present as a function of time?

3. [10 Marks Total]

   For a planar source of neutrons, S neutrons / cm^2 sec, in an infinite absorbing medium, we know that the flux distribution is given by:

$$\varphi = \frac{SL}{2D}\exp\left(-\frac{|x|}{L}\right)$$

where L is the diffusion length, D is the diffusion coefficient, and x is the distance from the planar source.

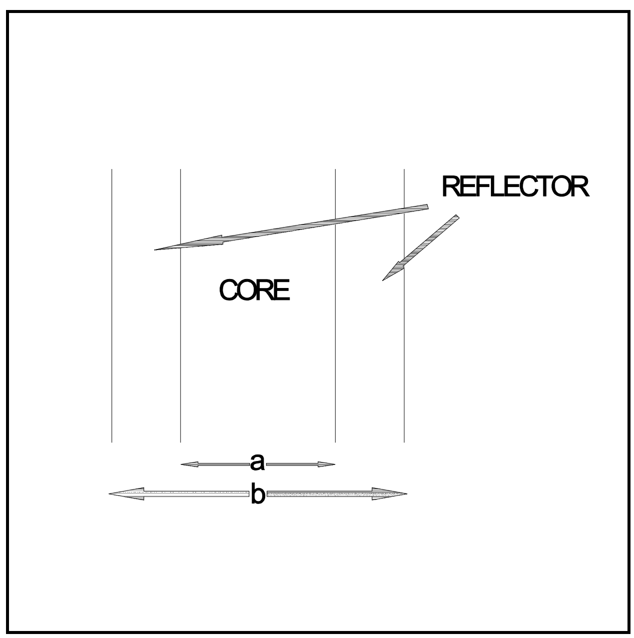
(7 marks)
a) Integrate over space to find the total absorption rate of neutrons in the right hand half of the absorbing medium.

(3 marks)
b) Compare (a) to the current at the source plane.

4. [10 Marks Total]

Consider a homogeneous, critical reactor in the shape of a finite cylinder. The radius, R, and length, L, are such that the reactor's volume is a minimum, ie., this configuration represents the smallest critical mass possible for this geometric shape. The geometric buckling, B_g^2, is composed of a radial buckling and an axial buckling. What is the ratio of the radial buckling to the axial buckling?

5. [15 marks total]



For an infinite cylindrical reactor with a reflector boundary as shown:

(4 marks)
a) State the 2 group diffusion equations for the core and reflector regions. Assume no upscatter.

(4 marks)
b) State and justify your boundary conditions.

(4 marks)
c) Outline the procedure for solving the above equations. Don't solve the equations; it is quite time consuming. Indicate how you would find the criticality equation.

(3 marks)
d) Sketch the flux distributions. Explain any significant features.

6. [15 Marks Total]

(5 marks)
a) The general multigroup neutron diffusion equations with delayed precursors are given by:

$$\frac{1}{v_g}\frac{\partial \phi_g}{\partial t} = \nabla\cdot D_g \nabla\phi_g - \Sigma_{a_g}\phi_g - \Sigma_{s_g}\phi_g + \sum_{g'=1}^{G}\Sigma_{s_{g'g}}\phi_{g'}$$
$$+ \chi_g \left[\sum_{g'=1}^{G} \nu_{g'}(1-\beta_{g'})\Sigma_{f_{g'}}\phi_{g'} + \sum_{i=1}^{N}\lambda_i C_i \right] + S_g^{ext}$$

$$\frac{\partial C_i}{\partial t} = -\lambda_i C_i + \sum_{g=1}^{G}\beta_{i_g}\nu_g\Sigma_{f_g}\phi_g$$

Define each variable. Explain the significance ofeach term.In these equations, what does "tightly coupled" imply? What does " no upscattering imply"?

(5 marks)
b) Group collapse the equations in (a) to the one group approximation. Show the intermediate steps.

(5 marks)
c) Simplify the equations by assuming that the half lives of all the delayed neutrons are very short (ie., virtually instantaneous decay).

7. [10 marks total]

Consider a long fuel pencil in an axially flowing coolant. The flux shape is a cosine in the axial direction. Derive an expression for the steady state temperature of the fuel pencil as a function of axial position. Assume that the fuel pencil has no sheath.

[Hint: You can get the centerline temperature of the fuel as a function of local power and coolant temperature. Also, you can get the coolant temperature as a function of axial position independent of fuel temperature.]

8. [15 Marks Total]

Following the approach of the term project, outline the theory and the procedure for a computer program to solve the 2 group neutron space-time diffusion equations in a one-dimensional slab reactor with a heterogeneous core /coolant /moderator, ie, space-time dependent parameters. Include 1 delayed precursor group. Ignore thermalhydraulic effects but consider the possible effects of burnup, poisoning and control. Remember, this is a space-time problem. Focus on:

a) the materials library
b) the cell definition
c) the grid
d) the model
e) the numerics
f) the control
g) the fuel management.

Do not get hung up on details but there should be a flow in your discussion. Display evidence that you not only understand the details but you have some mastery of the overall picture.

THE END