ENGINEERING PHYSICS 4D3/6D3

DAY CLASS — Dr. Wm. Garland

DURATION: 50 minutes

McMASTER UNIVERSITY MIDTERM EXAMINATION #2 — November 24, 2003

Special Instructions:

1. Closed Book. All calculators and up to 6 single sided 8 ½" by 11" crib sheets are permitted.
2. Do all questions.
3. The value of each question is as indicated. TOTAL Value: 100 marks

THIS EXAMINATION PAPER INCLUDES 2 PAGES AND 6 QUESTIONS. YOU ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR INVIGILATOR.

1. [10 marks] Distinguish between neutron density, neutron current, neutron flux, and neutron fluence.

F1991 g1a

n = density [≡] #/cm³ $\phi = nv$ [≡] #/cm²-s = number passing through a surface per unit time.

$\underline{J} = n\underline{v}$ [≡] #/cm²-s = directional flow (vector)

Φ ≡ fluence = $\int_0^t \phi\, dt$

2. [15 marks] 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 $\Sigma_a = 103\ cm^{-1}$.

Boron is a good absorber, ∴ safe to assume negligible scattering (no buildup)

F1991 g1b

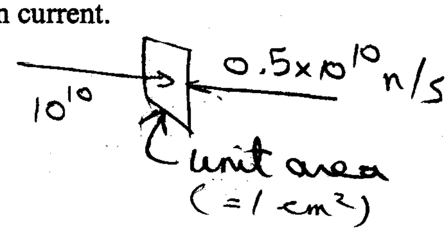
$\therefore \frac{I(x)}{I(0)} = 0.001 = e^{-\Sigma_a x} \Rightarrow x = -\ln(0.001)/\Sigma_a = \frac{+6.91}{103}$

$\Rightarrow x = 0.0671$ cm.

3. [15 marks] 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.

$\phi = 1 \times 10^{10} + 0.5 \times 10^{10}$ n/cm²-s

$= 1.5 \times 10^{10}$ n/cm²-s



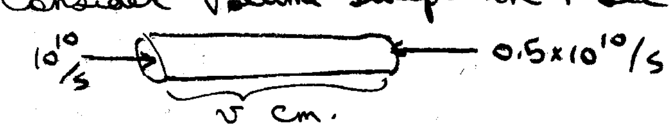
(assuming the unit area is 1 cm²

$\underline{J} = 1.0 \times 10^{10} - 0.5 \times 10^{10}$ n/cm²-s

$= 0.5 \times 10^{10}\ \hat{x}$ n/cm²-s (positive x direction)

OR

Consider Volume swept in 1 sec



Vol. contains 1.5×10^{10} n ∴ $n = \frac{1.5 \times 10^{10}}{v \times 1\ cm^2}$

∴ $\phi = nv = 1.5 \times 10^{10}$/cm²-s, etc.

4. [15 marks] For a planar source of neutrons in an infinite medium, we found that the neutron flux distribution (assuming one speed) falls of as exp (-x/L) where $L^2=D/\Sigma_a$. Why doesn't it fall off as per the simple beam attenuation, exp $(-\Sigma_t x)$?

based on F 2001 q6B

Simple beam attenuation does not consider neutron diffusion (multiple scatters).

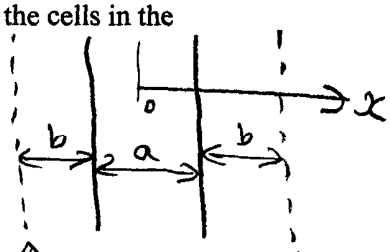
5. [30 marks] Consider a large one dimensional reactor composed of many replicated identical cells, each containing fuel and moderator. Each cell consists of a central fuel region of thickness "a" surrounded on either side by a moderator of thickness "b". Near the centre of the reactor, we can assume that one cell looks and behaves like its neighbours since the reactor is large. Thus, the flux distribution in each central cell can be calculated independently. Assume one speed neutrons.

a. What are the governing flux equations for the steady state for the cells in the central region of the reactor?

M 1998 q 2

fuel: $D_F \frac{\partial^2 \phi_F}{\partial x^2} + (\nu\Sigma_{f_F} - \Sigma_{a_F})\phi_F = 0$

mod: $D_m \frac{\partial^2 \phi_m}{\partial x^2} - \Sigma_{a_m}\phi_m = 0$



repeated cell i.e. reflective B.C.

b. What are the boundary conditions for these cells?

(1) $\frac{\partial \phi_F}{\partial x}\Big|_{x=0} = 0$ (symmetry ∴ slope of ϕ at $x=0$ is 0.)

(2) $\phi_F\big|_{x=a/2} = \phi_m\big|_{x=a/2}$

(3) $J_F\big|_{x=a/2} = J_m\big|_{x=a/2}$

$\Rightarrow D_F \frac{\partial \phi}{\partial x}\Big|_{x=a/2} = D_m \frac{\partial \phi}{\partial x}\Big|_{x=a/2}$

(4) Reflection at cell boundary

$J_m\big|_{x=a/2+b} = 0$

$\Rightarrow \frac{\partial \phi_m}{\partial x}\Big|_{x=a/2+b} = 0.$

6. [15 marks] Consider an infinite sub-critical reactor with k = 0.6. Show that an original 100 neutrons are multiplied up to a total of 250.

original 100 → 100 × k → (100 × k) × k → ...

i.e. total # = $100(1+k+k^2+k^3+\dots) = 100 \times \frac{1}{1-k} = \frac{100}{0.4} = 250$

- END -