ENGINEERING PHYSICS 4D3/6D3

DAY CLASS Dr. Wm. Garland

DURATION: 50 minutes

McMASTER UNIVERSITY MIDTERM EXAMINATION October 27, 1994

Special Instructions:

1. Open Book. All calculators and reference material permitted.
2. Do all questions.
3. The value of each question is 25 marks.
   TOTAL Value: 75 marks

THIS EXAMINATION PAPER INCLUDES 1 PAGE AND 3 QUESTIONS. YOU ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR INVIGILATOR.

1. Consider a planar thermal neutron source, S neutrons / cm^2 in the middle of a slab of concrete of thickness, a cm.
   a) What is the probability that the neutron will pass from the centre to the edge without a collision?
   b) What is the probability that it will ultimately diffuse from the centre to the edge?

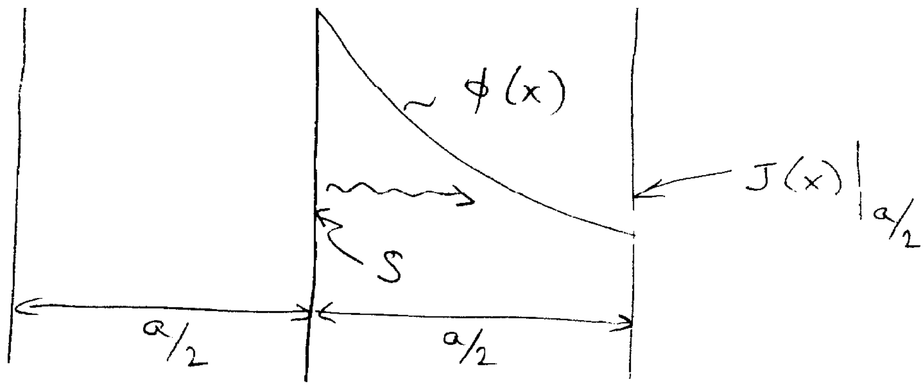
2. A free neutron beta decays with a half-life of 11.7 minutes. Determine the relative probability that a neutron will undergo beta decay before being absorbed in an infinite medium. Calculate this probability using water, $\Sigma_A = 0.022 cm^{-1}$, as the medium. HINT: Distance = speed x time. Compare the following probabilities:
   - the probability of travelling some distance, x, without being absorbed or decaying and then decaying at x
   - the probability of travelling distance, x, without being absorbed or decaying and then getting absorbed at x.

3. Given the material properties for a homogeneous fuel water mixture, determine whether a cubic shaped reactor requires more or less mass than a cylindrical shaped reactor for criticality. Assume that the cylindrical reactor has the optimal shape that you determined in a recent assignment:

$$\frac{Radius}{Height} , \frac{2.405}{\sqrt{2}\Pi}$$

4D3 Midterm Solutions — Oct 27/94

1.



Soln:

a) Probability of going from $x=0$ to $x=a/2$ without interaction is given by:

$$I(x) = I(0)e^{-\Sigma_t x} \Rightarrow \text{Prob} = e^{-\Sigma_t x}\Big|_{x=a/2}$$

$$\boxed{\text{prob} = e^{-\Sigma_t a/2}}$$

since this is just like a neutron beam being attenuated in a target. Any collision puts the neutron out of the running since we want only the ones ~~that~~ have not interacted at all.

b) The actual leakage out the edge is given by the current, $J(x)|_{a/2}$. The fraction or probability is $\frac{J(x)|_{a/2}}{S/2}$.

Now we know the flux is $\phi(x) = \frac{SL}{2D}\frac{\sinh[(a-2x)/2L]}{\cosh(a/2L)}$

(recall: $\sinh x = \frac{e^{x}-e^{-x}}{2}$)

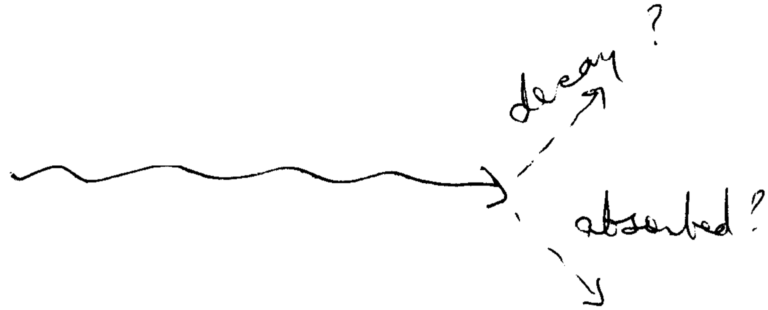
$$\therefore J(x)|_{a/2} = \frac{-DSL}{2D}\left[\frac{-\frac{1}{L}e^{(a-2x)/2L} - \frac{1}{L}e^{0}}{\cosh(a/2L)}\right] = \frac{S}{2}\cdot\frac{1}{\cosh(a/2L)}$$

$$\therefore \boxed{\text{prob} = \frac{1}{\cosh(a/2L)}}$$

decay ↙ ↙ absorption

2. $dn = -\lambda n\,dt - \Sigma_a n\,dx$

$dx = v\,dt$



$\therefore \quad dn = -\lambda n\,dt - \Sigma_a n v\,dt$

$\therefore \quad \frac{dn}{dt} = -(\lambda + \Sigma_a v)n\,dt$

$\therefore \quad n = n(0)\, e^{-(\lambda + \Sigma_a v)t}$

ratio of decay/absorption $= \frac{\lambda n\,dt}{v \Sigma_a n\,dt}$

$= \frac{\lambda}{v \Sigma_a}$

Assume $v = 2.2 \times 10^5$ cm/sec (thermal neutrons)

$\Sigma_a = 0.022\ \text{cm}^{-1}$

$\lambda = \frac{\ln 2}{T_{1/2}} = \frac{0.693}{11.7 \times 60}\ \text{sec}^{-1} = 9.9 \times 10^{-4}\ \text{sec}^{-1}$

$\therefore \quad \frac{\lambda}{v \Sigma_a} = 2.04 \times 10^{-7}$

ie decay is not likely.

(25)

3. Cylinder $\frac{R}{L} = \frac{\nu_0}{\sqrt{2}\,\pi}$ $V = L\pi R^2$ cylinder.

$$B^2 = \left(\frac{\nu_0}{R}\right)^2 + \left(\frac{\pi}{L}\right)^2 = \frac{3\pi^2}{L^2}$$ for optimal R/L

For a cube of the same Buckling

$$B^2 = 3\left(\frac{\pi}{a}\right)^2$$

ie $\underline{L = a}$.

So now let's compare volumes of the cube & the cylinder.

Cylinder: $V = \pi L R^2 = \pi L \left(\frac{\nu_0}{\sqrt{2}\pi} L\right)^2 = \frac{\nu_0^2 L^3}{2\pi} = 0.92 L^3$.

Cube: $V = L^3$.

∴ Volume of cube for a critical reactor of Buckling, B^2 is > volume of cylindrical reactor of the same Buckling.

(25)

4. [30]

Assume the point kinetics model,

$$\frac{dn}{dt} = \left(\frac{\rho - \beta}{\Lambda}\right) n(t) + \sum_{i=1}^{6} \lambda_i C_i(t)$$

$$\frac{dC_i}{dt} = \frac{\beta_i}{\Lambda} n(t) - \lambda_i C_i(t),$$

for a reactor. The reactor has been operating at neutron level n_1 for a very long time. The operator inserts a small amount of reactivity to slowly change the neutron level to n_2.

a) How do the delayed precursor concentrations vary before, during and after the neutron level change? Defend any assumptions you make to simplify your solution.

b) If the operator had inserted a reactivity equal to β (ie, made the reactor prompt critical), What would happen? Show mathematically and discuss.