ENGINEERING PHYSICS 4D3/6D3

DAY CLASS — Dr. Wm. Garland

DURATION: 20 minutes

McMASTER UNIVERSITY QUIZ — October 8, 1997

Special Instructions: Open Book. All calculators and reference material permitted.

THIS EXAMINATION PAPER INCLUDES 1 PAGE AND 1 QUESTION.

1. A spherical reactor composed of pure U-235 is critical in a vacuum. What happens, with respect to criticality, when:

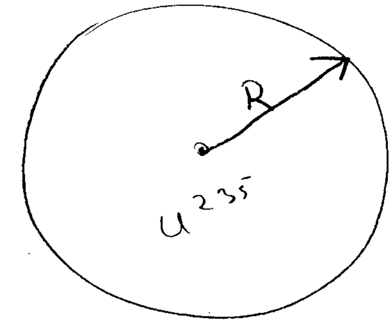
   a) the reactor is surrounded by cadium ($\Sigma_a = 3.69\ cm^{-1}$, $\Sigma_s = 0.352\ cm^{-1}$).

   b) the reactor is placed in a water bath ($\Sigma_a = 0.022\ cm^{-1}$, $\Sigma_s = 3.45\ cm^{-1}$).

For each case, write down (but do not attempt to solve) the 1 speed neutron diffusion equations and explain your reasoning in terms of these equations and the physical processes that the neutrons undergo.

ANSWER

a)



Cadium

Core

$$+D^c \frac{1}{r^2}\frac{\partial}{\partial r} r^2 \frac{\partial \phi^c}{\partial r} + (\nu\Sigma_f^c - \Sigma_a^c)\phi^c = 0$$

reflection to the core — leakage to the reflector

Reflector:

$$D^R \frac{1}{r^2}\frac{\partial}{\partial r} r^2 \frac{\partial \phi^R}{\partial r} - \Sigma_a^R \phi^R = 0$$

Neutrons diffuse out of core and, in a vaccum, these neutrons would be lost since a sphere is a non-rentrant surface. But with the cadium on the ouside, the neutrons will diffuse through it, although most will be absorbed by the cadium (high Σ_a). Note that Σ_s is not zero so there is some scattering, and hence diffusion going on. Recall that $D \sim \frac{1}{3\Sigma_{tr}}$. So a few neutrons will re-enter the core. Therefore the reactor will go supercritical. As we saw with the planar case, a reflected core has a smaller size than a non-reflected core.

In this case, cadium, normally used as an absorber, will make the reactor supercritical!

b) Same as case (a) except many more neutrons reflected ∴ even more supercritical.

ENGINEERING PHYSICS 4D3/6D3

DAY CLASS — Dr. Wm. Garland

DURATION: 20 minutes

McMASTER UNIVERSITY — QUIZ #2 — October 15, 1997

Special Instructions: Open Book. All calculators and reference material permitted.

THIS EXAMINATION PAPER INCLUDES 1 PAGE AND 1 QUESTION.

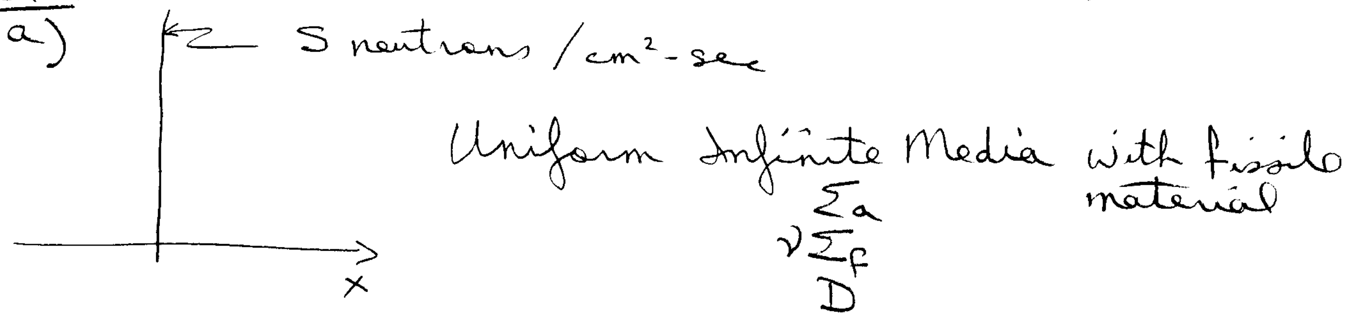
1. Consider an infinite planar neutron source, emitting S neutrons/cm^2-s, surrounded by a homogeneous infinite mixture of absorbing material and fissile material. The mixture is sub-critical. In essence, this is an infinite subcritical pile with a planar source. Assume one group diffusion applies.

(a)Derive the steady state flux distribution as a function of space. (60)

(b) What happens as the mixture approaches criticality? (40)

Sol'n

a)



$$D\frac{d^2\phi}{dx^2} + (\nu\Sigma_f - \Sigma_a)\phi = 0 \quad \text{for } x \neq 0$$

Compare this to case done in class for no fissile material:

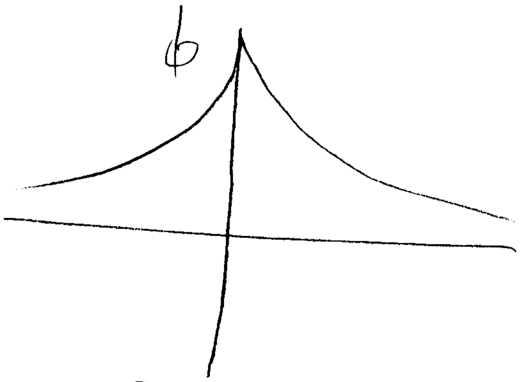
$$D\frac{d^2\phi}{dx^2} - \Sigma_a\phi = 0 \quad \text{for } x \neq 0.$$

This is the same except define $L^2 = D/\Sigma_a - \nu\Sigma_f$

$\therefore \quad \phi = \frac{SL}{2D} e^{-x/L}$ where ↗

b) Pile is initially subcritical, ie $\nu\Sigma_f$ is small cf Σ_a. As $\nu\Sigma_f \uparrow$, $(\Sigma_a - \nu\Sigma_f)\downarrow$ & thus $L\uparrow$. At some point $\nu\Sigma_f = \Sigma_a$ & fission birth = absorption. At this point any S neutron lives (effectively) forever (ie no net absorption). Beyond ~~that~~ (as $\nu\Sigma_f$ increases to ~~be~~ greater than Σa), the solution increases exponentially away from the source.

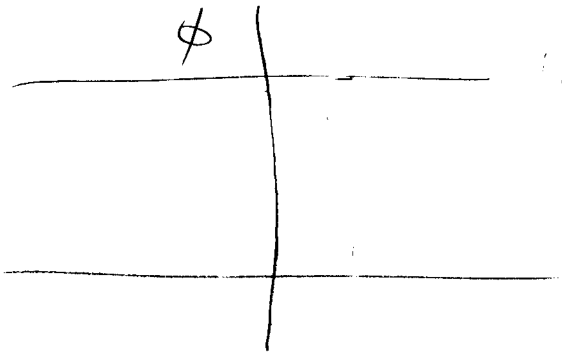
⟶ More



$$\phi = \frac{SL}{2D} e^{-x/L}$$

where $L > 0$

Case ①: $\nu \Sigma_f < \Sigma_a$



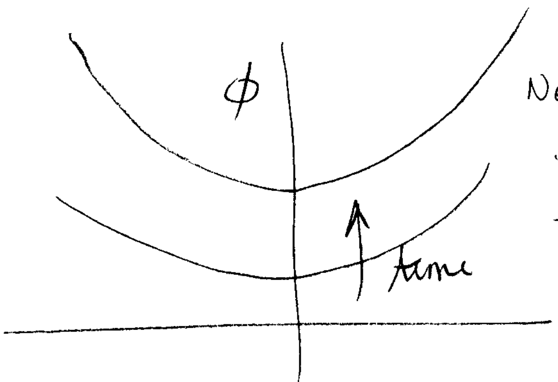
As $\nu \Sigma_f \to \Sigma_a$, $L \to \infty$

$$\phi \sim \frac{SL}{2D} e^{-x/L}$$

← very slow decay in space.

Large increase in amplitude.

Case ② $\nu \Sigma_f = \Sigma_a$



Note: Steady state does not hold, ∴ need to solve transient equation for this runaway reactor.

Case ③ $\nu \Sigma_f > \Sigma_a$