

Final Exam – 22.05

Fall 2008

Part I (40 points total / 4 pts each)

Question 1

Write down the alpha decay reaction of the Pu-240 (see chart of nuclides in Appendix).

Question 2

Explain how an alpha emitter can be used to create a neutron source.

Question 3

Draw the fission product distribution curve for a fission stemming from a thermal neutron capture and explain how it behaves if the neutron has higher energy (10 MeV).

Question 4

Explain the presence of resonances in neutron interaction with nuclei's and explain the differences seen between light and heavy nucleus.

Question 5

Explain what causes the Doppler Effect. Discuss its effect on the neutron cross-section and its importance in reactor theory

Question 6

Explain briefly the differences (or lack thereof) between a PWR and a CANDU reactor for the following topics:

- fuel enrichment
- coolant/moderator
- excess reactivity during operation
- reactivity coefficients (fuel temperature and coolant void)

Question 7

List three instances where diffusion theory fails.

Question 8

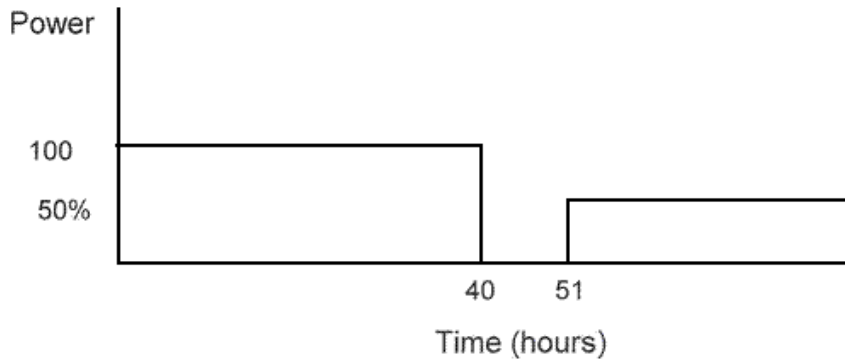
Discuss concisely the impact of fuel temperature change in a thermal reactor using the 4-factor formula.

Question 9

Describe concisely the neutron life cycle in a thermal reactor in terms of the 6-factor formula.

Question 10

A reactor is initially xenon-free. Draw the xenon concentration for the following power profile.



Part II (60 points total)

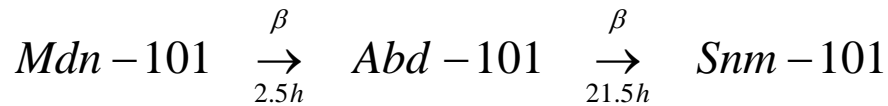
Question 11 (15 points)

A point source of strength S_p is located at the center of a sphere of a non-multiplying medium with properties D and Σ_a , and an extrapolated radius R_{exp} , in an infinite vacuum.

- Find the flux distribution in the sphere (8 points)
- Determine the fraction of neutrons that escape from the sphere without being absorbed if $R_{exp} = L$. (7 points)

Question 12 (20 points / 5 points each)

In a new reactor design, Madeupdenum-101 is a fission product produced with a yield of 0.07. It then undergoes the following decay:



Although the absorption cross-section of Mdn-101 and Snm-101 are negligible, the absorption cross-section of Abd-101 is 3×10^6 barns. Suppose that the reactor has been operating at a flux level of 1×10^{14} n/cm²/s for several months and an average macroscopic fission cross section of 0.4 cm^{-1} .

- Write down the differential equations that determine the concentration change in time of Mdn(t) and Abd(t)
- Determine the expressions for equilibrium concentrations of Mdn and Abd
- Solve for Mdn(t) and Abd(t) following a reactor shutdown (assume the flux goes to zero).
- Determine the time of peak concentration of Abd following shutdown (indicate any approximations made)

	σ_a (barns)	Fission Yield (γ)
Mdn-101	0	0.07
Abd-101	3×10^6	0
Snm-101	0	0

Question 13 (10 points)

A critical reactor has been operating at constant power (10 MW) for quite some time. Suddenly a control rod is ejected from the core (control rod worth 0.2\$). Ten seconds after the rod ejection, an unnamed feedback mechanism intervenes to make the core critical again. Consider all reactivity changes to be step functions. Using the one delayed group point kinetics equations and neglecting spatial variations, xenon effects and all other feedback effects:

- Evaluate the power level 10 seconds after the rod ejection. (3 points)
- For the power transient in the first 10 seconds, evaluate the prompt and stable periods. (4 points)
- Plot the power transient that you would anticipate for the first 100 seconds. (3 points)

$$\beta = 0.006$$

$$\Lambda = 0.00001 \text{ s}$$

$$\lambda = 0.1 \text{ s}^{-1}$$

Question 14 (15 points)

Starting from the 1 group diffusion equation, derive the criticality condition for a slab with no source surrounded by a vacuum. The properties of the slab are D , Σ_a and $\nu\Sigma_f$ (neglect the extrapolated distance)

Appendix

Chart of Nuclides

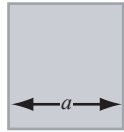
94	^{237}Pu 45.2 D ϵ : 100.00% α : 4.2E-3%	^{238}Pu 87.7 Y α :100.00% sF: 1.9E-7%	^{239}Pu 24110 Y α :100.00% sF: 3.E-10%	^{240}Pu 6561 Y α :100.00% sF: 5.7E-6%	^{241}Pu 14.290 Y β^- :100.00% α : 2.5E-3%
	^{236}Np 153E+3 Y ϵ :86.30% β^- :13.50%	^{237}Np 2.144E+6 Y α :100.00% sF \leq 2E-10%	^{238}Np 2.117 D β^- :100.00%	^{239}Np 2.356 D β^- :100.00%	^{240}Np 16.9 M β^- :100.00%
92	^{235}U 7.04E+8 Y 0.7204% α : 100.00% sF: 7.0E+9%	^{236}U 2.342E7 Y α : 100.00% sF: 9.4E-8%	^{237}U 6.75 D β^- : 100.00%	^{238}U 4.468E9 Y 99.2742% α : 100.00% sF: 5.5E-5%	^{239}U 23.45 M β^- : 100.00%
	143	145	147		

Image by MIT OpenCourseWare.

Geometric Buckling B_g^2

Flux profile

Slab



$$\left(\frac{\pi}{\tilde{a}}\right)^2$$

$$\cos \frac{\pi x}{\tilde{a}}$$

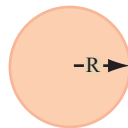
Infinite Cylinder



$$\left(\frac{\nu_0}{\tilde{R}}\right)^2$$

$$J_0\left(\frac{\nu_0 r}{\tilde{R}}\right)$$

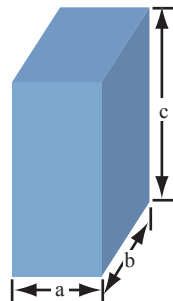
Sphere



$$\left(\frac{\pi}{\tilde{R}}\right)^2$$

$$r^{-1} \sin\left(\frac{\pi r}{\tilde{R}}\right)$$

Rectangular Parallelepiped



$$\left(\frac{\pi}{\tilde{a}}\right)^2 + \left(\frac{\pi}{\tilde{b}}\right)^2 + \left(\frac{\pi}{\tilde{c}}\right)^2$$

$$\cos\left(\frac{\pi x}{\tilde{a}}\right) \cos\left(\frac{\pi y}{\tilde{b}}\right) \cos\left(\frac{\pi z}{\tilde{c}}\right)$$

Finite Cylinder



$$\left(\frac{\nu_0}{\tilde{R}}\right)^2 + \left(\frac{\pi}{\tilde{H}}\right)^2$$

$$J_0\left(\frac{\nu_0 r}{\tilde{R}}\right) \cos\left(\frac{\pi z}{\tilde{H}}\right)$$

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