Chemical Engineering 412

Introductory Nuclear Engineering

Lecture 24

Exam 2 Review

Spiritual Thought

"Just as it is important to prepare ourselves spiritually, we must also prepare ourselves for our temporal needs. Each of us needs to take the time to ask ourselves, What preparation should I make to care for my needs and the needs of my family?

We have been instructed for years to follow at least ***four*** requirements in preparing for that which is to come.

First, gain an adequate education.

Second, live strictly within your income and save something for a rainy day.

Third, avoid excessive debt.

Fourth, acquire and store a reserve of food and supplies that will sustain life…

'If ye are prepared ye shall not fear'"

Elder L. Tom Perry

Chapter 10 (I)

- Chapter 10
  - Criticality
    - Six factor formula
    - Multiplication factor
    - Cross Sections
    - Neutron Life Cycle
  - Moderation
    - Common moderators
    - Most effective moderators
  - Bare Reactor
    - Flux profiles
    - Boundary conditions
    - Diffusion Equation Problems

Chapter 10 (II)

- Homogenous vs. heterogeneous
- Buckling
  - Geometric
  - Material
  - Constituents
  - How to size reactor
- Transient Reactor Behavior
  - Delayed neutrons
  - reactivity
  - δk
  - Reactor worth ($)
  - Reactor operation
  - Period and times

Chapter 10 (III)

- Poisons
  - Reactivity insertions
  - Reactivity “swing”
  - Reactor control methods
  - Long term reactivity changes and countermeasures
  - Changes in time
- Reactivity Coefficients
  - Doppler
  - Void (moderator expansion)
  - Axial Expansion
  - Radial Expansion
  - Control Rod Drive Expansion
  - Calculate change in reactivity based on given coefficients

Chapter 11 (I)

- Nuclear Energy Conversion
  - Key Components
  - General layout of nuclear plant systems
- Light Water Reactors
  - Components
  - Configurations
  - Design
  - Challenges
  - Operation
  - BWR vs PWR
- Operation Perturbations
  - Thermal Changes
  - Load Changes
  - Fuel Changes
  - Accidents

Chapter 11 (II)

- Gen IV Reactors
  - Know types
  - Benefits/Disadvantages
  - Know fuel types, coolants, fuel forms, spectrums
- Evolution of Nuclear Power
  - Generations
  - Characteristics
  - Other Non-LWR (non Gen IV)
- Fast Reactors
  - Breeder vs. Burner
  - Key Components
  - Challenges
  - World-wide use

Chapter 12

- heat output of radioactive isotopes.
- GPHS
  - Characteristics
  - Table 12.2
- RTGs
  - Types
  - Differences & Similarities
- Electricity generation at any point in the life of an RTG.
- Space reactor concepts

Example 1: Rod Ejection Accident

- A control rod is ejected from the core instantly adding \$0.0005 reactivity to the core. Assuming we want a temperature increase of no more than 10 ºC, what is the minimum overall reactivity feedback coefficient (in %mil/ºC) that we must design for the core?

$k(\$), \Delta T \quad \frac{k(\$)}{\Delta T} = 5 \frac{\%mil}{°C}$

$-5 \frac{\%mil}{°C} \cdot \Delta T - \$.0005$

- If water contributes 1 %mil/ºC of negative feedback, how much should the soluble Boron provide?

Find τ?

	β	$T_{\frac{1}{2},d}(s)$
^{232}Th	0.0203	6.98
^{233}U	0.0026	12.4
^{235}U	0.0064	8.82
^{238}U	0.0148	5.32
^{239}Pu	0.002	7.81
^{241}Pu	0.0054	104.1
^{241}Am	0.0013	10
^{243}Am	0.0024	10
^{242}Cm	0.0004	10

Example 2: Reactor Dynamics

How long does it take for a ^{233}U reactor at light-bulb power (10 W) to reach 1 MW and 1 GW with a 0.08($) reactivity insertion?

$\delta k \ll 1$, so Eq 10.17 indicates period or e-folding time

$$T = \frac{\beta\tau}{\delta k} = \frac{\beta\tau}{k_{eff} - 1} = \frac{\beta\tau}{k_{eff}\rho} = \frac{\tau}{k_{eff}\rho(\$)} \approx \frac{\tau}{\rho(\$)}$$

$$= \frac{17.9s}{0.08} = 223.6\ s$$

Example 2: Reactor Dynamics (cont.)

$$t = T \ln \frac{P(t)}{P(0)}$$

For 10 W → 1 MW

$$t = 223.8s \ln 10^5 = 2576\text{s} = 42.9\text{min}$$

For 10 W → 1 GW

$$t = 223.8s \ln 10^8 = 4122\text{s} = 68.7\text{m}$$

Example 3: Ragnarok

- Turns out Asgard runs on fission and fusion, and the eternal flame used to bring about Ragnarok is generated by thermal fission (hence why it's eternal) reaction. We know it's an exactly critical water and uranium reactor in a 60 cm diameter infinite cylinder that generates the heat. What is the ratio of fuel to moderator for this reactor?