School of Energy Systems
Nuclear Engineering

BH30A2105 Nuclear Reactor Dynamics **Exam 2026-03-26**

Instructions:

- Allowed: pen(cil), eraser, ruler, function calculator.
- Not allowed: written material.
- Language: answers either in English or Finnish.

Question 1 (6 points)

Explain terms AND answer questions below

(a) (1 points) Delayed neutrons. Is it possible to operate light water reactor without having delayed neutrons?

(b) (1 points) Prompt jump. When does the prompt jump occur and why?

(c) (1 points) Reactivity coefficient. Describe a self-regulating process of BWR in case of positive reactivity insertion.

(d) (1 points) Conversion. Describe conversion process from U-238 to Pu-239.

(e) (1 points) Multibatch loading. What advantages and disadvantages this method has?

(f) (1 points) Excess reactivity. What is used in PWRs and BWRs to compensate excess reactivity?

Question 2 (6 points)

Explain how power is controlled in a boiling water reactor. How the reactor is maintained critical over the operating cycle. How does a BWR plant respond to generator load variation?

TURN!

Question 3 (6 points)

When using one group for delayed neutrons the following approximate solution for the amount of neutrons can be derived

$$n \approx n_0 \cdot \left(\frac{\beta}{\beta-\rho} \cdot \mathrm{e}^{\frac{\lambda\rho}{\beta-\rho}\cdot t} - \frac{\rho}{\beta-\rho} \cdot \mathrm{e}^{-\frac{\beta-\rho}{\Lambda}\cdot t} \right)$$

How does the reactor behave in the following cases? Draw an approximate sketch on paper using a graphical calculator (or using calculated values of relative power for at least 3 time points) to visualize the power as a function of time and explain what happens and why.

a) $\rho = 300\,\mathrm{pcm}$, $\beta = 650\,\mathrm{pcm}$ ($^{235}\mathrm{U}$)

b) $\rho = -300\,\mathrm{pcm}$, $\beta = 650\,\mathrm{pcm}$ ($^{235}\mathrm{U}$)

c) $\rho = 740\,\mathrm{pcm}$, $\beta = 650\,\mathrm{pcm}$ ($^{235}\mathrm{U}$)

d) $\rho = 300\,\mathrm{pcm}$, $\beta = 230\,\mathrm{pcm}$ ($^{239}\mathrm{Pu}$)

Use the following constant values in all cases:

$\lambda_{\mathrm{U-235}} = 0.085\,\frac{1}{\mathrm{s}}$, $\lambda_{\mathrm{Pu-239}} = 0.070\,\frac{1}{\mathrm{s}}$, $\Lambda = 5 \times 10^{-4}\,\mathrm{s}$

Question 4 (6 points)

In a graphite moderated molten salt reactor control rods are pulled out of the core by some amount. Due to this, the core temperature increases 25 °C and the fuel salt density decreases $0.1\,\frac{\mathrm{g}}{\mathrm{cm}^3}$.

- Density coefficient of reactivity of fuel salt $\alpha_{\rho,\mathrm{f}} = 750\,\mathrm{pcm/g/cm^3}$
- Doppler coefficient of reactivity of fuel salt $\alpha_{\mathrm{D,f}} = -5\,\mathrm{pcm/°C}$
- Temperature coefficient of reactivity of moderator $\alpha_{\mathrm{T,m}} = 1\,\mathrm{pcm/°C}$

Calculate the reactivity effect of the control rod movement $\Delta\rho_{\mathrm{cr}}$.

Question 5 (6 points)

Pu-239 is generated in a reactor through a conversion process when U-238 captures a neutron. Immediately after some Pu-239 is generated, the conversion process continues and Pu-239 gets converted to Pu-240 through another neutron capture. Pu-239 may also experience fissions. You can neglect the radioactive decay of Pu-239 considering that the half-life is very long. Calculate how much Pu-239 (in kg) is produced in 150 days in a uranium fueled light water reactor. Use the constant values given below.

$$\begin{array}{lll} \sigma_{\mathrm{c,U-238}} = 2.71\,\mathrm{b} & \sigma_{\mathrm{f,Pu-239}} = 742\,\mathrm{b} & m_{\mathrm{UO_2}} = 30\,000\,\mathrm{kg} \\ \sigma_{\mathrm{c,Pu-239}} = 287\,\mathrm{b} & w_{\mathrm{U-235}} = 4.5\,\% & \varphi = 10^{13}\,\frac{1}{\mathrm{cm^2 s}} \end{array}$$

Possibly useful Integrals (integration constant C omitted):

$$\int \frac{x}{ax+b}dx = \frac{x}{a} - \frac{b}{a^2}\ln|ax+b|, \quad \int \frac{dx}{ax+b} = \frac{1}{a}\ln|ax+b|, \quad \int \frac{dx}{x(ax+b)} = -\frac{1}{b}\ln\left|\frac{ax+b}{x}\right|$$