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PHYS-E0460 Introduction to Reactor Physics, 2nd mid-term exam **1 Dec 2025**

You may use an unprogrammed calculator and the document "Mathematical Tools for Reactor Physics". You are welcome to answer in English, Finnish or Swedish.

1. Give a concise explanation of the following terms:
   a) cruciform rod   b) α_{prompt} c) temperature defect
   d) critical heat flux q''_{crit} e) Reynolds number   f) segregation

2. The time behavior of an infinite homogeneous reactor is described by the equations

$$t_d \frac{d\phi(t)}{dt} = [(1-\beta)k_\infty - 1]\phi(t) + \frac{p}{\Sigma_a}\sum_{i=1}^{6}\lambda_i C_i(t)$$

$$\frac{dC_i(t)}{dt} = \beta_i \frac{k_\infty}{p}\Sigma_a \phi(t) - \lambda_i C_i(t).$$

   Explain the meaning of the various quantities and terms, and derive from these the reactivity equation. Describe the asymptotic behavior of the solution of the reactivity equation.

3. The fission product poison ^{135}Xe is produced in the reaction chain

$$\text{fission} \rightarrow {}^{135}\text{Te} \xrightarrow[\text{T}_{1/2}=19\text{s}]{\beta^-} {}^{135}\text{I} \xrightarrow[\text{T}_{1/2}=6.57\text{h}]{\beta^-} {}^{135}\text{Xe} \xrightarrow[\text{T}_{1/2}=9.14\text{h}]{\beta^-} {}^{135}\text{Cs} \xrightarrow[\text{T}_{1/2}=2.3\times10^6\text{a}]{\beta^-} {}^{135}\text{Ba (stable)}.$$

   The first three nuclides are produced also directly from fission. Let's approximate that the half-lives of the nuclides preceding ^{135}I are small compared to the Xe poisoning time scale (i.e. that all ^{135}I is produced directly from fission), and that iodine doesn't absorb neutrons ($\sigma_{a,I} = 0$). The yields of I and Xe from fission are γ_I and γ_X and the thermal flux is ϕ_T.
   a) Formulate the rates of change of iodine and xenon concentrations dI/dt and dX/dt at constant reactor power and solve their concentrations $I(t)$ and $X(t)$.
   b) Formulate the rates of change of iodine and xenon concentrations dI/dt and dX/dt after shutdown following a long time at constant power and solve $I(t)$ and $X(t)$.
   c) Describe qualitatively what kind of consequence the xenon poisoning can have if a reactor shutdown from high power occurs near the end of core life (at high burn-up)?

4. A pebble bed reactor (PBR) has spherical fuel elements of uranium carbide (UC_2) with a fuel radius R and a passive cladding of thickness a. Determine the temperature distribution in the fuel element when the power of the sphere is P, the outer surface temperature is T_c and the thermal conductivity is k_f in the fuel and k_c in the cladding. Hint: ∇^2 is given in the supplementary material, and only the $\partial/\partial r$ term is relevant. You can assume the power density in an individual fuel element to be constant.

5. Describe the lessons learned by the nuclear power industry from the 1979 Three Mile Island (TMI-2) accident and the overall effect this has had on nuclear power plant safety.