**Georgia Institute of Technology**

The George W. Woodruff School of Mechanical Engineering

Nuclear and Radiological Engineering/Medical Physics Program

PhD Qualifying Exam

Fall 2019

\_\_\_\_\_\_\_\_\_\_\_

(Your ID Code)

**Nuclear Engineering**

**Reactor Physics**

**(Day 2)**

**Instructions**

1. Use a separate page for each answer sheet using only the front side of the paper. DO NOT write on the back of the answer sheet
2. The **question number and your ID Code** should be shown clearly on each answer sheet
3. **ANSWER 4 OF 6 Questions in this exam**
4. Staple your question sheet to your answer sheet and turn in

**Reactor Physics Question 1**

A core fueled with 100 ton (4.5% weight enriched) of uranium operates under a nominal power of 3400 MWth. The following simplified transmutation chain is given:

$$fission\rightarrow Pm^{149}\begin{matrix}β^{-}\\\rightarrow \\t\_{1/2}=53 hr \end{matrix}Sm^{149}\begin{matrix}(n,γ)\\\rightarrow \\σ=40×10^{3} b \end{matrix}$$

In addition, the fission yield for *Pm* is $γ^{Pm}=0.0113$. The half-life of Sm149 is extremely long and the cross-section of Pm149 is negligible. Assume that U235 is the only fissile isotope with an effective one-group cross-section of$ σ\_{f}=30 b$. Assume the nuclide density of U235 is not changing.

1. Write the differential equations that describe the rate of change for Pm149 and Sm149.
2. Calculate the concentration (# of atoms) of Sm149 at equilibrium.
3. Calculate the concentration of Sm149 following a shutdown of 20 days.
4. Draw the reactivity worth shape of Sm149 following a shutdown and explain/justify your drawing

**Reactor Physics Question 2**

The power of a core is required to be doubled in 5 minutes. Before the transient, the core operated at a steady state with a nominal power of *P0*.

1. Calculate the stable period.
2. Calculate the inserted reactivity to satisfy this increase.

Data: $=0.08 s^{-1}$ , $β=0.0065$

**Reactor Physics Question 3**

A bare homogeneous spherical core produces 15 MWth. The radius of the core is 100 cm. Calculate the power density (W/cm3) of the core at the point z=7 cm, y=4 cm, z=-22 cm. The coordinate’s origin is positioned at the center the spherical core. Neglect the extrapolation length.

**Reactor Physics Question 4**

Using diffusion theory, compute the buckling of a critical, 150 MWth, fast reactor made of mixed oxide fuel disbursed uniformly in a 10-cm by 10-cm by 20-cm configuration. Assume that $υΣ\_{f}=0.2$ cm-1 and the transport mean free path $λ\_{tr}$ at all surfaces of this reactor is 4-cm.

**Reactor Physics Question 5**

Consider a homogeneous slab consisting of uranium-235, the neutrons are essentially all fast ($E\geq 100 $ kev) and, as a first approximation, all the neutrons may be considered to have the same energy.

1. Write down the diffusion equation, assuming isotropic scattering and vacuum boundary condition.
2. Calculate the critical thickness. The following data are to be used: uranium density 10.88 $g/cm^{3}$, $σ\_{f}=1.3 $barns, $σ\_{s}=4.0 $barns, $σ\_{c}=0$, and $\overbar{ν}=2.5$.

**Reactor Physics Question 6**

For a homogeneous purely scattering infinity medium, there is a source $s\left(z,E\right)=S\left(E\right)$ for $z\in (-\infty ,\infty )$.

* 1. Write down the neutron slowing down equation, assuming the scattering cross section is $Σ\_{s}\left(E^{'}\rightarrow E,\hat{Ω}'\rightarrow \hat{Ω}\right)=\frac{1}{4πE^{'}}$ for $E\in [0,E^{'}]$.
	2. Derive the lethargy (u) dependent slowing down equation from (a)