Example Review Questions

A Few General Info

- <u>These questions are only examples! They don't reflect exam questions but might guide you in your study and reasoning!</u>

- ***Exam will be written on Wednesday 02.07.2025 from 09h15 to 12h15 (AAC 2 31)***

- The exam will be structured as a combination of
  - Multiple choice questions → cover your understanding of basics aspects covered in class.
  - Sketch or complete the sketch questions.
  - *Simpler* exercises where you need to apply the basic formulas seen in class.
  - One or two *more complex* exercise for extra points.

Nuclear Physics

Atomic physics review

- What are the main components of an atom? What is their mass and size (at least relative)?
- Can you write the correct formula of an atom? What is Z and what is A?
- What are molar mass and atomic weight? ***Can you calculate how many at. are in a certain mass of a substance?***

Nuclear physics basics

- Explain the concept of isotope. Remember the natural concentration of U-235, and the names/concentration of H-isotopes.
- What is a stable isotope and what is a radioactive one? ***Sketch the Z-vs-N plot of stable isotopes.***
- Sketch BE/A vs A curve. What does it tell us about nuclear reactions?
- ***Can you complete a nuclear reaction (given enough info)?***
- Compare the energy involved in nuclear processes with the ones involved in chemical reactions.
- Remember typical energies involved in fusion and fission reactions.

Nuclear Physics

Radioactivity

- Can you describe three “main” modes of radioactivity?
- ***Can you complete the decay of an isotope by knowing its mode of decay?***
- ***Can you understand the decay path of an isotope by its position on the nuclide chart?***
- What is the fundamental law of radioactivity?
- What is activity and what is its unity? How does radioactive decay evolve with time?
- What is half-life and how does it relate to decay constant?

Neutron behavior

- How do neutrons interact with matter? What are the various types of interactions that we have discussed? What is neutron capture? What is fission?
- What is a cross-section (micro- and macro-)? What does it measure and how do we use them to calculate reaction rates?
- What cross-sections depend on? Can you roughly sketch a XS dependency on energy?
- How do we classify neutrons based on their energy?
- What is the quantity we use in nuclear engineering to measure the neutron population?

Fission Reaction

Fission reaction characteristics

- Write a generic fission reaction (with ~energy).
- ***What is the distribution or yield of fission products? Sketch the double hump curve.***
- How many neutrons are emitted per fission? What is their energy on average? ***Sketch neutron energy curve.***
- ***Are all neutrons emitted at the exact moment of fission? Where do delayed neutrons come from?***
- ***Roughly remember the energy balance of a fission reaction.***
- Are fission products stable? What is decay heat and why is it relevant? How does decay heat roughly evolves with time?

Fission Reaction

Chain reaction

- What is a nuclear chain reaction? What characteristic of the fission process makes it possible?
- What is a fissionable material? What about fissile and fertile? Remember main fissile isotopes.
- Explain the concept of multiplication factor and criticality. What do we mean with k_{inf} and k_{eff}?
- Write simple balance equation without explicitly expressing the various terms.
- What is the factor η?
- What is minimum value required for η for the reactor to be critical?
- ***What is the minimum value for η to have a breeder? (Why would we want a breeder?)***
- ***Can you sketch eta as a function of energy? What is the main consequence for breeder reactors?***
- How are leakages and size related?

Reactor Technology

- What are the main ingredients of a nuclear reactor? Sketch a generic nuclear reactor.
- What is a moderator and why do we need it?
- What is the main mean of control of the chain reaction?
- Sketch a PWR and/or a BWR. ***The more details in the scheme, the better (but no high-quality drawing required)***
- ***Can you sketch the correct flow-path of water in a LWR?***
- How is reactor core arranged? Describe a fuel rod. Remember characteristic dimensions and numbers.
- How many circuits are present for a reactor? How many loops?
- What other components are present in a PWR primary circuit? ***Can you simply explain the role of the pressurizer?***
- How much energy typically we produce from NPPs? What is the efficiency? What limits this efficiency?
- ***Can you calculate how much mass flow rate is needed to evacuate the energy generated in the reactor?***
- Difference in containment between PWR and BWR.

Neutron Transport

- What is the goal of neutronics? What information does it provide us?
- ***Can you write a simple expression for k_{inf}? How are k and k_{inf} related? What is the buckling? Why do we talk about geometrical and material buckling?***
- Explain the concept of criticality condition, i.e. $B_m = B_g$. How can you use the criticality condition? How is it related to composition and size?
- ***Can you express k as a function of the buckling?***
- ***What about the n on-leakage probability?***

- Can you recall the 4- and 6-factor formula?
- Do you remember the meaning of each term?

- Why are we interested in neutron slowing down? How do neutrons lose energy in the reactor?
- Does the amount of energy lost in a collision depend on the nucleus mass number? If yes, how?
- ***What is the logarithmic lethargy loss and how does it change with A?***
- What characteristics we need to consider when selecting a good moderator material?

Reactor Kinetics

- How can k change during irradiation?
- What is reactivity?
- What is the main approximation of reactor point kinetics?
- Can you explain how the reactor power would evolve in the absence of delayed neutrons?
- What changes when we take into account the delayed neutrons? Do you have a rough physical explanation for this difference?
- When is this change valid and why the limit is rho = beta?

- Explain doppler feedback.
- Explain water temperature feedback? How do we make our reactors intrinsically safe?

Reactor Thermal Analysis

- Why do we need technological limits for the design of nuclear reactors?
- Explain difference between linear power, heat flux and volumetric power?
- Heat balance equation for a 1D fuel pellet.
- Explain the concept of thermal resistance and how we can use it for a fuel rod.
- Using the concept of fuel thermal resistance, what is the first technological limit?
- What is the technological limit related to cladding? Why do we choose Zircaloy?
- What is the technological limit related to water? What is boiling crisis? Why do we choose water?

Summer Internship, TP4 & master projects

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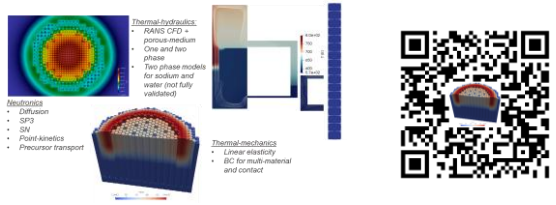
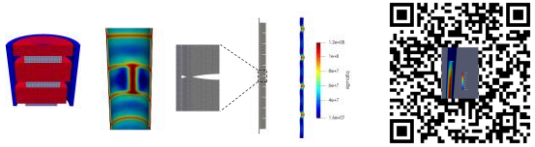
LRS research in one slide

GeN-Foam Multiphysics Solver

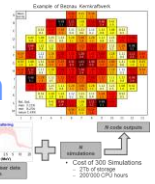


Code development

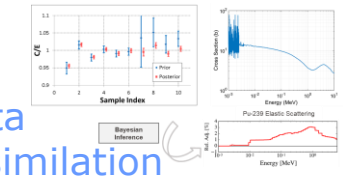
OFFBEAT Fuel Behavior Solver



Uncertainty Quantification

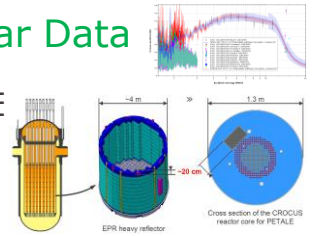


Data Assimilation



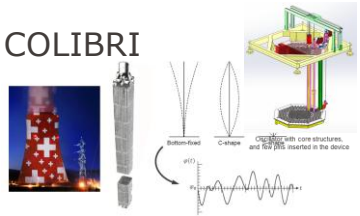
Nuclear Data

PETALE

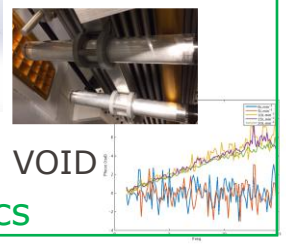


Reactor Physics Experiments

COLIBRI

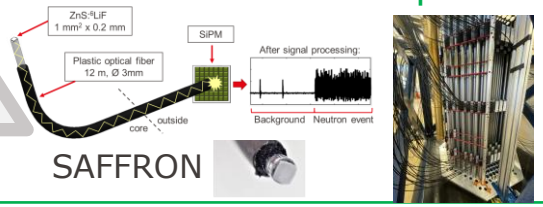


VOID



Reactor diagnostics

Instrumentation development

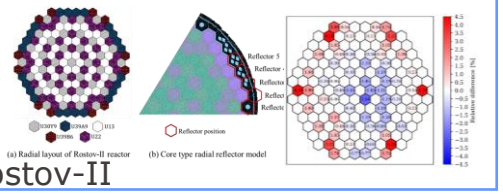


SAFFRON

Reactor Physics

Verification & Validation

International Benchmarks

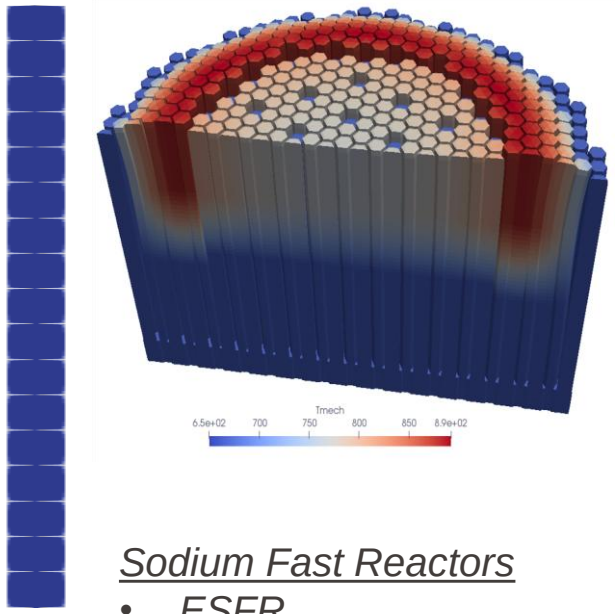


Rostov-II

Code development

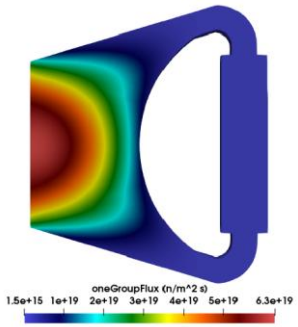
In-house open-source codes based on the OpenFOAM C++ library:

- **GeN-Foam for multiphysics analysis of reactor core**
- **OFFBEAT for fuel behavior and mechanics**

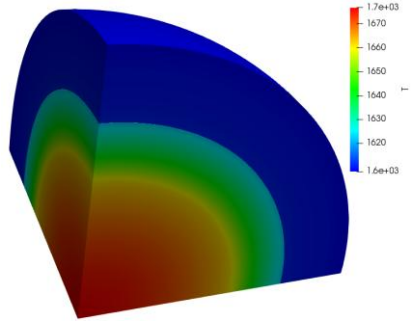


Sodium Fast Reactors

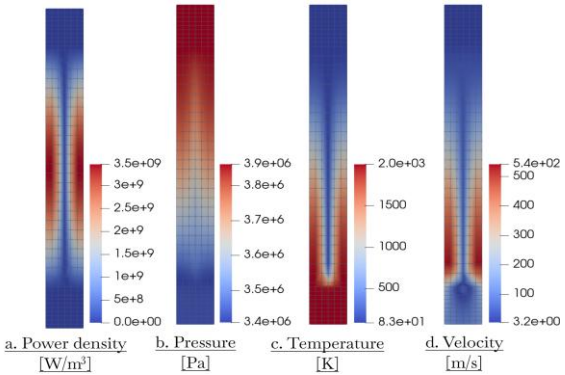
- *ESFR*
- *ESFR-SMART*
- *Super Phenix*



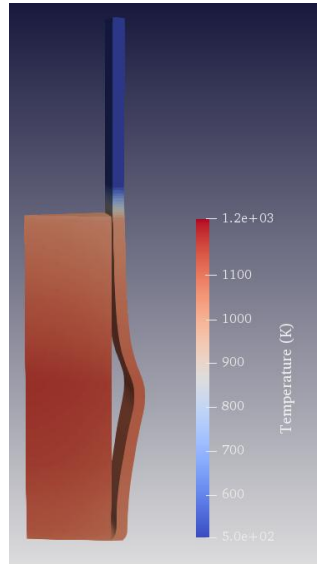
Molten Salt Reactors (MSRE, MSFR)



Temperature distribution in a TRISO particle



KIWI space reactor (NTP)



LOCA – Ballooning