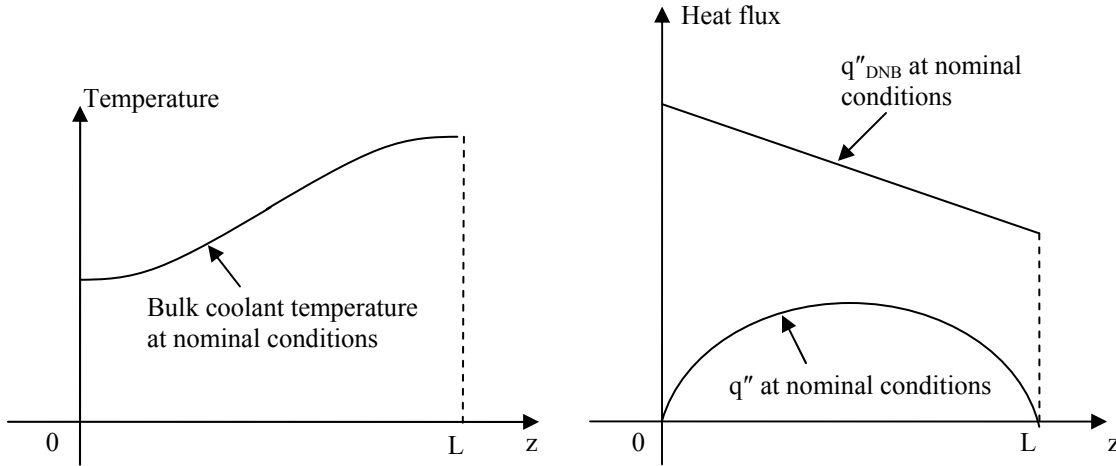


Short Questions (10% each)

- a) The specific power in a UO_2 pellet of a certain LWR is $q''=200 \text{ W/cm}^3$. The fuel ^{235}U enrichment is 4 % by weight. The total density of uranium in the pellet is 9.3 g/cm^3 . Assuming all energy generated comes from ^{235}U fissions, calculate the neutron flux (ϕ) in the pellet. Nuclear data for ^{235}U : 200 MeV/fission , $\sigma_f=577 \text{ b}$.
- b) Water flows in a round channel (diameter $D=2 \text{ cm}$, length $L=2.5 \text{ m}$) at 0.5 kg/s and 5 MPa . The flow is subject to a heat flux that varies axially as $q''(z) = q''_{\max} \sin\left(\frac{\pi z}{L}\right)$, where $q''_{\max}=300 \text{ kW/m}^2$. The inlet temperature is 260°C .
- Find the axial location, z_{sat} , at which the coolant becomes saturated. (Useful properties of saturated water at 5 MPa : $c_{p,f}=5 \text{ kJ/kg-K}$, $h_f=1155 \text{ kJ/kg}$, $h_g=2794 \text{ kJ/kg}$, $T_{\text{sat}}=264^\circ\text{C}$)
 - Find the steam quality at the channel outlet.

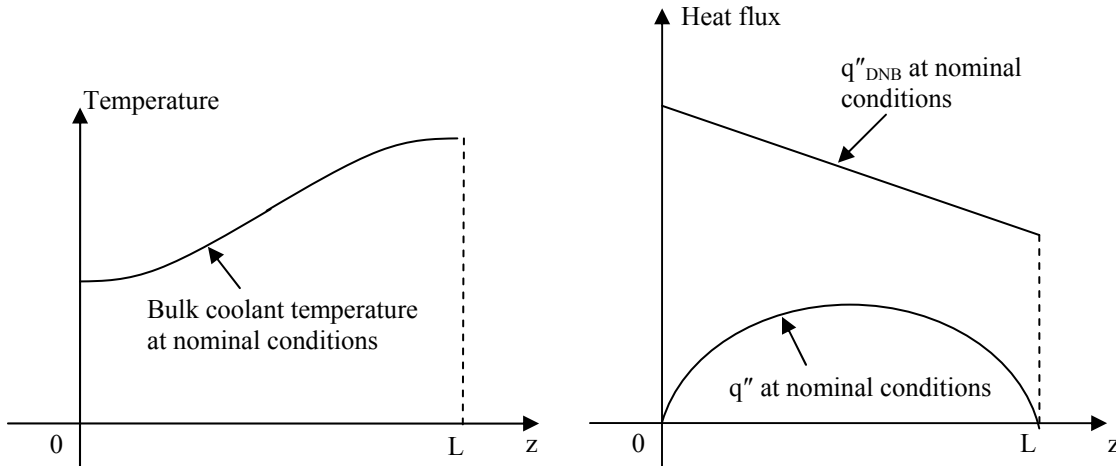
c) Consider a PWR fuel assembly operating at nominal power, flow rate and inlet temperature, with a cosine shape heat flux profile. Sketch qualitatively the curves describing the axial profile of the bulk coolant temperature, the operating heat flux (q'') and the DNB heat flux (q''_{DNB}) at the following conditions:

i) Higher flow rate, nominal power and inlet temperature



Does the MDNBR increase, decrease or stay the same with respect to the nominal conditions?

ii) Higher inlet temperature, nominal power and flow rate



Does the MDNBR increase, decrease or stay the same with respect to the nominal conditions?

Problem 1 (50%) - Calculating the Mass Flow Rate for a Prescribed Pressure Drop

To improve the thermal-hydraulic performance of an Advanced High-Temperature Reactor (AHTR), a vendor wishes to compare two alternative coolants, i.e., a liquid metal (Na) and a liquid salt (LiF-BeF₂). In the AHTR core the coolant flows inside 10-m long round channels arranged in a hexagonal lattice and surrounded by a solid fuel matrix. Consider the unit cell of this core (Figure 1).

The friction pressure drop in the coolant channel, ΔP_{fric} , is to be limited to 250 kPa.

- i) Calculate the maximum allowable mass flow rate for the two candidate coolants. (30%)
- ii) Assuming the bulk coolant temperature at the channel inlet is 600°C, and the heat flux is equal to 200 kW/m² (uniform axially and circumferentially), calculate the maximum temperature of the channel surface for both coolants. (20%)

Assumptions:

- In selecting a suitable friction factor correlation, you may assume $Re > 30,000$, neglect surface roughness and entry region effects.
- In selecting a suitable heat transfer correlation, you may neglect entry region effects.

Relevant properties are reported in the table below.

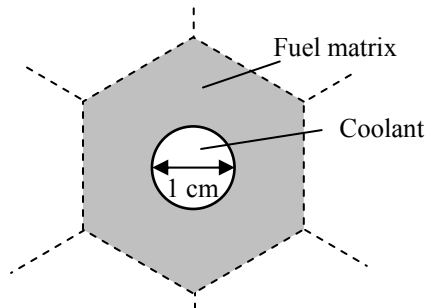


Figure 1. Cross sectional view of the core unit cell.

Coolant properties (independent of temperature and pressure)

Material	ρ (kg/m ³)	k (W/m-K)	μ (Pa·s)	c_p (J/kg-K)
Liquid Na	780	60	1.7×10^{-4}	1,300
Liquid LiF-BeF ₂	1,940	1	2.0×10^{-3}	2,410

Problem 2 (20%) - Sizing the Silicon Carbide Layer in a TRISO Fuel Particle

A TRISO fuel particle can be modeled as a small spherical pressure vessel of radius 280 μm and with the wall made of silicon carbide (SiC). The internal pressure is due to the build-up of fission gases, while the external pressure is a constant 8 MPa (i.e., the pressure of the reactor coolant). At the end of the irradiation cycle the fuel particle contains 0.1 μmol ($=10^{-7}$ moles) of fission gases and operates at 950°C.

Estimate the minimum required thickness of the SiC wall to prevent failure.

Assumptions:

- Use a thin-shell approximation and the Von Mises failure criterion for your analysis.
- Assume the fission gases occupy only 30% of the volume within the fuel particle.
- The fission gases can be treated as a perfect gas ($R=8.31$ J/mol-K).

Properties of SiC at 950 °C

Yield strength: 200 MPa

Density: 3200 kg/m^3

Young's modulus: 400 GPa

Poisson's ratio: 0.28

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