**22.312 ENGINEERING OF NUCLEAR REACTORS**

Due November 16, 2005 by 12:00 pm

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TAKE HOME QUIZ #2

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**Problem 1 (80%) – Coolant selection for an advanced high-temperature reactor**

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 ($LiF-BeF_2$). 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).

i) The friction pressure drop in the coolant channel is to be limited to 200 kPa. Calculate the maximum allowable mass flow rate for the two candidate coolants. (Neglect surface roughness and entry effects) (15%)

ii) Calculate the pumping power for the mass flow rates computed in 'i'. (Assume $\eta_p$=100%) (5%)

iii) The coolant temperature at the channel inlet is 600°C. Assuming that the temperature in the fuel cannot exceed 1000°C, calculate the maximum allowable linear power for each coolant. (*Hint:* approximate the geometry of the fuel around the coolant channel as an equivalent annulus that conserves the fuel volume. Then solve the heat conduction equation for this annulus with a zero heat flux boundary condition. Assume axially and radially uniform heat generation rate within the fuel) (55%)

iv) In view of the above results, which coolant should the vendor select and why? (5%)

The properties for all materials in the system are reported in Table 1 below.

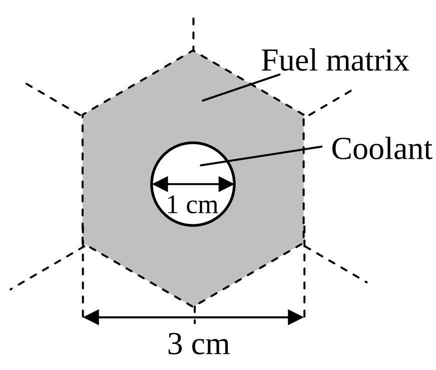
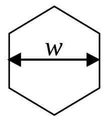



**Figure 1. Cross sectional view of the core unit cell.**

**Table 1. Properties** (all properties constant with temperature)

| **Material** | **ρ (kg/m$^3$)** | **k (W/m·K)** | **μ (Pa·s)** | **$c_p$ (J/kg·K)** |
|---|---|---|---|---|
| **Liquid Na** | 780 | 60 | $1.7\times10^{-4}$ | 1,300 |
| **Liquid LiF-BeF$_2$** | 1,940 | 1 | $2.0\times10^{-3}$ | 2,410 |
| **Fuel matrix** | 8,530 | 6 | / | 500 |

***Hexagon area:*** $A = \frac{\sqrt{3}}{2} w^2$




## Problem 2 (20%) – Flow split in downflow

High-pressure water at mass flow rate $\dot{m}$ enters a certain component comprising an inlet plenum and an outlet plenum, connected by two vertical tubes (Figure 2). These two tubes are identical except that one is heated and one is cooled. Is the mass flow rate in each tube the same? If not, which tube has the higher mass flow rate? (*Hint:* it is recommended to use equations to support your answer)

Assume the following:
- The density of water decreases as temperature increases
- Downflow exists in both tubes
- The form and acceleration terms in the momentum equation are negligible
- The friction factor is the same in both tubes
- Single-phase and steady-state conditions apply

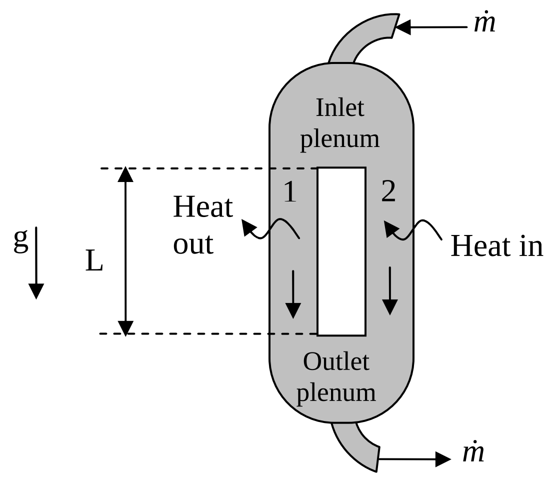



**Figure 2. Parallel vertical channels.**