RESERVE DESK

OCT 19 2001

GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff School of Mechnical Engineering

NRE/HP Qualifier Exam

Fall Semester 2001

________________________ Your ID Code

Thermal-Hydraulics

Instructions

1. Use a separate page for each answer sheet (no front to back answers).
2. The question number should be shown on each answer sheet.
3. Answer 4 of 6 questions.
4. Staple your question sheet to your answer sheets and turn in.

1. The core of a 3100 MWt PWR contains 193 fuel assemblies each loaded with 520 kg of UO_2. The average enrichment in the core is 3.2%, while the effective thermal fission cross section is 350 barns. [Av = 0.602252 × 10^{24} molecules/g-mole; 1 Mev = 1.6021 × 10^{-13} Joules].

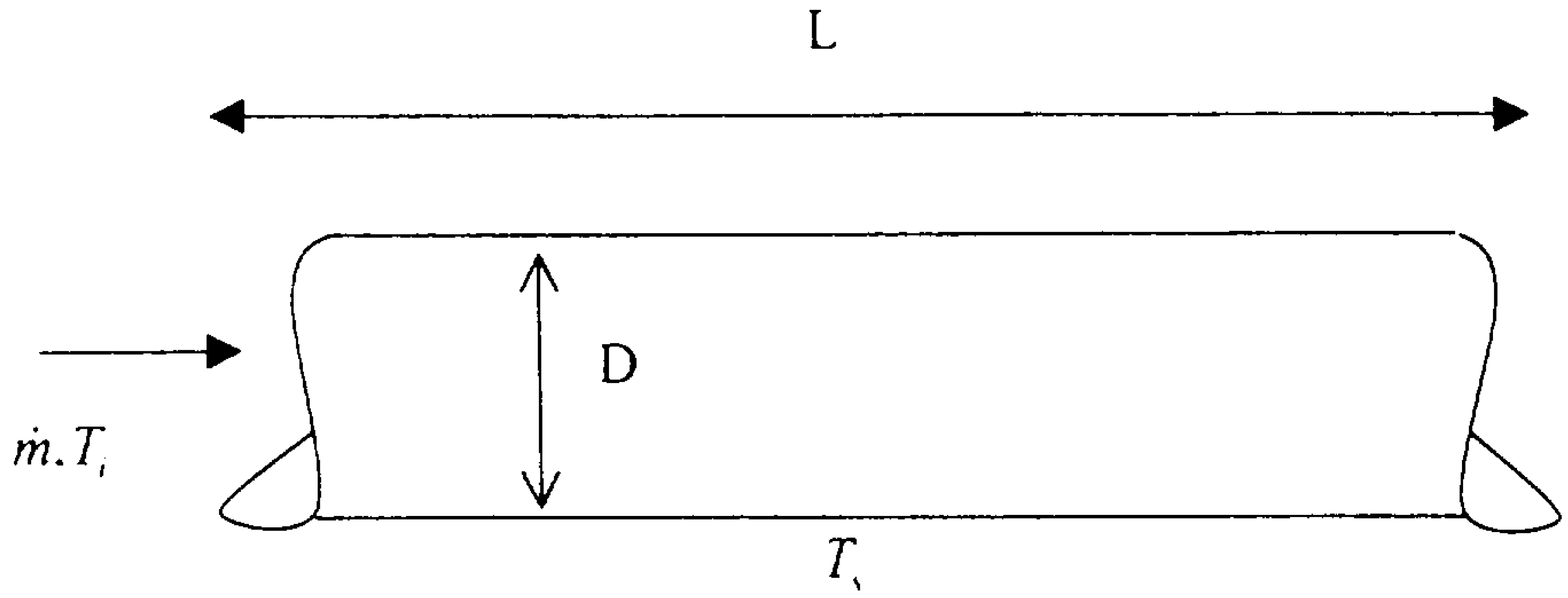
   a. Evaluate the average thermal neutron flux in the core.
   b. Evaluate the average volumetric heat generation rate in the fuel material. Assume the fuel material density to be 92% of the theoretical value (ρ_{TD} = 10.97 g/cc).
   c. Calculate the average linear power of the fuel rods, assuming there are 207 fuel rods per assembly with an active fuel rod length of 3.8 m.
   d. Calculate the average heat flux at the cladding outer surface, assuming the cladding outer diameter to be 10 mm.

2. By means of temperature-entropy diagrams, show how the thermal efficiency, net work output, and heat input for an ideal Rankine cycle would be affected by the following changes (while all other parameters remain unchanged):

   a. Increasing steam temperature.
   b. Increasing steam generator pressure.
   c. Decreasing condenser pressure.

3. Consider a thin plate-type fuel element 6.0 mm thick. Heat is generated uniformly within the fuel material at a rate of 1.0×10^6 kW/m^3. The thermal conductivity of the fuel material may be assumed constant and equal to 3.0 W/m °C. Because of the coolant flow arrangement within the core, the coolant temperature and heat transfer coefficient on one surface of the plate are 300 °C and 100 W/m^2 °C, while the corresponding values on the other surface are 270 °C and 120 W/m^2 °C, respectively. Ignoring cladding, determine the location and magnitude of the peak fuel material temperature.

4. A fluid with specific heat C_p and mass flow rate $\dot{m}$ flows in the channel shown. The tube surface temperature, T_s, is constant. Derive an expression for total heat transfer rate, q, in terms of $D, L, \dot{m}, C_p, T_i, T_s$ and the average convection heat transfer coefficient $\bar{h}$.



5. Give the definition of the following two-phase pressure multipliers:

$\phi_{lo}^2 ; \phi_g$

Derive expressions for the above parameters for a one-dimensional homogeneous flow using the following two correlations.

- Fanning friction factor

$$f = 0.079\ \mathrm{Re}^{-0.25}$$

- Homogeneous two-phase viscosity

$$\mu_{TP} = \left(\frac{x}{\mu_g} + \frac{1-x}{\mu_l} \right)^{-1}$$

6. a) Describe the regimes of heat transfer, two-phase flow, and boiling, associated with the flow of subcooled water in a uniformly-heated channel, and plot the expected quality, and void fraction profiles.

b) Using the correlation of Saha and Zuber (1974), for a channel with $D = 1\,cm$ diameter subject to water with $T_m = 80^oC$ and $u_m = 0.3\,m/s$, assuming atmospheric pressure, find the location where onset of significant void (OSV) takes place. The heat flux is 500 kW/m².

- Saha-Zuber correlation

$$h_f - h_l = 0.0022 \quad \frac{q'' D_h C_{pl}}{k_l} \; for\; Pe < 70{,}000$$

$$h_f - h_l = 154\, q''/G \qquad for \quad Pe > 70{,}000$$

$$Pe = G\, D_h C_{pl} / k_l$$

Properties of water

$$\rho_l = 967 \quad kg/m^3$$
$$k_l = 0.676 \quad W/mk$$
$$C_{pl} = 4200 \quad J/kgK$$
$$\nu_l = 0.34x10^{-6} m^2/s$$
$$\Pr = 2.0$$

- Dittus-Boetler correlation for convection heat transfer:

$$Nu = 0.023 \quad Re^{0.8} \Pr^{0.4}$$