1) A fountain is being designed that would have \( n \) fluid streams as illustrated below. Develop the equations necessary to determine the pump work to produce a stream height \( H \), and give the step by step solution procedure you would use. You may assume the pool height is effectively equal to the nozzle height. All lines can be considered commercial steel. You may assume fluid property tables and the Moody friction factor chart is available.

2) A Boiling Water Reactor is to be designed such that the critical power ratio in the highest powered channel is no less than a known MCPR. For the given information, show how you would determine the total core thermal output. You may assume a known Critical Boiling Length correlation of the form

\[
x_{\text{crit}} = \frac{a(G, P)L_{\text{crit}}}{L_{\text{crit}} + b(G, P)}
\]

and a heat flux profile of the form

\[
q^*(z) = q_0^*Z(z)
\]

where \( Z(z) \) is a known function of axial position. You may also assume the highest powered channel is the channel with the highest heat flux.
BOILING WATER REACTOR PARAMETERS

- Core Thermal Output: $\dot{Q}$
- Fraction of Energy Deposited in Fuel: $\gamma_f$
- Power Peaking Factor: $F_q$
- Axial Peak to Average Ratio: $F_z$
- Pressure: $P$
- Core Mass Flux: $G_c$
- Number of fuel rods: $n_{rods}$
- Core Flow Area: $A_c$
- Fuel Height: $H_c$
- Rod Diameter: $D$
- Rod Pitch (square lattice): $S$
- Core Inlet Enthalpy: $h_{in}$

3) In the highest powered channel of a particular PWR, the fluid enters highly subcooled and exits as a very low quality saturated mixture. For a given heat flux profile $q^*(z)$ and the information given below:

a) Give a step by step procedure for determining the wall temperature distribution in the channel

b) Give a step by step procedure for determining the Minimum DNB Ratio in the channel.

You may assume a critical heat flux correlation of the form

$$q_{crit}^* = q_{crit}^{*}(G, P, x_e, D_e)$$

is available. For solutions requiring iteration, it is sufficient to give the iteration equations and state the variable to be solved for iteratively.

PRESSURIZED WATER REACTOR PARAMETERS

- Pressure: $P$
- Core Mass Flux: $G$
- Fuel Height: $H$
- Rod Diameter: $D$
- Rod Pitch (square lattice): $S$
- Core Inlet Enthalpy: $h_{in}$
You may find all or some of the following relationships useful.

**Mass**

\[ A_x \frac{\partial \rho}{\partial t} + \frac{\partial GA_x}{\partial z} = 0 \]

**Energy**

\[ A_x \frac{\partial u}{\partial t} + \frac{\partial GhA_x}{\partial z} = q'(z) \]

**Momentum**

\[
\frac{1}{g_c} \frac{\partial G}{\partial t} + \frac{1}{g_c} \frac{1}{A_x} \frac{\partial}{\partial z} \left[ \frac{G^2}{\rho} A_x \right] = -\frac{\partial P}{\partial z} \left[ \frac{f}{D_e} \frac{G^2}{2 \rho g_c} + \sum_j K_j \delta(z - z_j) \frac{G^2}{2 \rho g_c} \right] - \frac{\rho}{g_c} g \sin \theta + \Delta P' \]

**Heat Transfer Correlations**

- **Dittus-Boelter Correlation**
  \[ Nu = 0.023 \text{Re}^{0.8} \text{Pr}^{0.4} \]

- **Weisman Correlation**
  \[ Nu = C \text{Re}^{0.8} \text{Pr}^{0.7} \]

- **Nucleate Boiling Correlation**
  \[ q^* = \xi (P(T_w - T_{sat}))^m \]

- **Chen Correlation**
  \[ q^* = h_{io}(G,x,P)(T_w - T_{sat}) + h_{NB}(G,x,P,T_w)(T_w - T_{sat}) \]

- **Bergles and Rohsenow**
  \[ q^*(z) = q^*_{FC}(z) \left[ 1 + \left( \frac{q^*_{NB}(z)}{q^*_{FC}(z)} \right) \left( 1 - \frac{q^*_{NB}(z_n)}{q^*_{NB}(z)} \right) \right]^{2 \frac{1}{2}} \]
  \[ q^*(z_n) = 15.6 \text{Pr}^{1.156} [T_{io}(z_n) - T_{sat}]^{2.30} / \mu^{0.024} \]