1) A tank of area $A_1$ is connected to a second tank of area $A_2$ through a line of area $A_0$. Both tanks are initially empty. At time $t = 0$ a source or water is allowed to discharge into tank 1 at a known rate $\dot{m}$. The discharge point is above tank 1 as illustrated in Figure 1 below. Develop an equation for the difference in the water levels in the two tanks as a function of time. You may assume the line between the two tanks is initially filled with water and the bottoms of the tanks are at the same elevation. You may also assume all flow losses can be characterized by a known constant loss coefficient $K_0$, referenced to the velocity in the connecting line. Both tanks are open to atmosphere.

![Figure 1: Connected Water Tanks](image)

2) Figure 2 below illustrates portions of two flow boiling curves.

   a) Under what operating conditions would you expect each of the curves?

   b) Discuss the heat transfer mechanisms associated with the regions of each curve. Be sure to explain the difference in the shapes of the curves.

   c) Discuss the critical heat flux mechanism associated with each curve.

   d) For which critical heat flux mechanism would you expect the resulting temperature excursion to be the greatest? Justify your answer.

![Figure 2: Flow Boiling Curves](image)
3) Given an arbitrary heat flux profile \( q'(z) \), mass flux \( G \), channel inlet enthalpy \( h_{\text{in}} \), channel pressure \( P \) and channel dimensions \( H, A_x, P_w, S \) and \( D_o \):

a) Show how you would determine which boiling curve was applicable

b) Give a step by step procedure for determining the maximum wall temperature if boiling curve (a) were applicable. Give all equations.

c) Give a step by step procedure for determining the maximum wall temperature if boiling curve (b) were applicable. Give all equations.

If your solution requires iteration, it is sufficient to give the iteration equation(s), state which variable(s) are to be iterated on and state “solve iteratively”.

4) Critical heat flux in a uniformly heated channel has been found to be dryout dominated. The critical heat flux can be correlated with a critical heat flux correlation \( q'' = q''(x, G, P) \) with an associated minimum critical heat flux ratio MCFR. Given the channel mass flux \( G \), channel inlet enthalpy \( h_{\text{in}} \), channel pressure \( P \) and channel dimensions \( H, A_x, P_w, \) and \( D_o \), show how you would determine the critical power ratio (CPR) for this channel associated with the MCFR. If your solution requires iteration, it is sufficient to give the iteration equation(s), state which variable(s) are to be iterated on and state solve iteratively.

You may find all or some of the following relationships useful.

**Mass**

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

**Energy**

\[
A_x \frac{\partial \rho}{\partial t} + \frac{\partial (G h A_x)}{\partial z} = q'(z)
\]

**Momentum**

\[
\frac{1}{g_c} \frac{\partial G}{\partial z} + \frac{1}{g_c} \frac{1}{A_x} \frac{\partial}{\partial z} \left( \frac{G^2}{\rho} A_x \right) = -\frac{\partial P}{\partial z} \left( \frac{G^2}{2 \rho g_c} \right) + \sum_j K_j \delta(z-z_j) \left( \frac{G^2}{2 \rho g_c} \right) - \rho \frac{g_s}{g_c} \sin \theta + \Delta P' + \int \rho \partial (\theta) \delta A_x \partial \rho \delta A_x \partial
\]

**Heat Transfer Correlations**

**Dittus-Boelter Correlation**

\[
Nu = 0.023 \text{Re}^{0.8} \text{Pr}^{0.4}
\]

**Weisman Correlation**

\[
Nu = C \text{Re}^{0.8} \text{Pr}^{\frac{1}{7}}
\]

**Nucleate Boiling Correlation**

\[
q'' = \xi(P)(T_w - T_{\text{sat}})^m
\]

**Chen Correlation**

\[
q'' = h_{\text{co}}(G, x, P)(T_w - T_{\text{sat}}) + h_{\text{NB}}(G, x, P, T_w)(T_w - T_{\text{sat}})
\]
Bergles and Rohsenow

\[ q^*(z) = q_{PC}^*(z) \left[ 1 + \left( \frac{q_{NB}^*(z)}{q_{PC}^*(z)} \left( 1 - \frac{q_{NB}^*(z_n)}{q_{NB}^*(z)} \right) \right)^2 \right]^{1/2} \]

\[ q^*(z_n) = 15.6 P^{1.156} [T_{co}(z_n) - T_{sat}]^{2.30} e^\mu (1014) \]