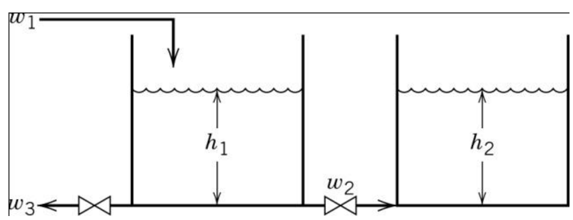
Q.1 A perfectly stirred, constant-volume tank has two input streams, both consisting of the same liquid, and one output stream. The temperature and flow rate of each of the streams can vary with time. Note that the liquid properties are constant (not functions of temperature)

(a) Derive a dynamic model that will describe transient operation.

(b) Simplify your model, if possible, to one or more differential equations by eliminating any algebraic equations. Also make a degree of freedom analysis assuming that both input streams come from upstream units.

Q.2 A completely enclosed stirred-tank heating process is used to heat an incoming stream whose flow rate varies. The heating rate from this coil and the volume are both constant. Develop a mathematical model that describes the exit temperature if heat losses to the ambient occur and if the ambient temperature (T_a) and the incoming stream temperature (T_i) both can vary.

Q.3 Two tanks are connected together in the following diagram



Develop a model for this system that can be used to find h_1, h_2, w_2, w_3 as functions of time for any given variations in inputs.
Note that the density of the liquid is constant.
The cross-sectional areas of the two tanks are A_1 and A_2.
W_2 is positive for flow from tank 1 to tank 2.
The two valves are linear with resistances R_2 and R_3.

Q.4 A process tank has two input streams – stream 1 at mass flow rate w_1 and stream 2 at mass flow rate w_2. The tank, effluent stream, at flow rate w, discharges through a fixed valve to atmospheric pressure. Pressure drop across the valve is proportional to the flow rate squared. The cross sectional area of the tank, A is 5 m^2, and the mass density of all streams is 940 kg/m^3.

(a) Draw a schematic diagram of the process and write an appropriate dynamic model for the tank level. What is the corresponding steady-state model?

(b) At initial steady-state conditions, with $w_1 = 2.0$ kg/s and $w_2 = 1.2$ kg/s, the tank level is 2.25 m. What is the value of the valve constant (give units)?

(c) A process control engineer decides to use a feed forward controller to hold the level approximately constant at the set-point vale ($h_{sp} = 2.25$ m) by measuring w_1 and manipulating w_2. What is the mathematical relation that will be used by the controller? If the w_1 measurement is not very accurate and always supplies a value that is 1.1 times the actual flow rate, what can you conclude about the resulting level control? (Hint: Consider the process initially at the desired steady-state level and with the feedforward controller turned on. Because the controller output is slightly in error, w_2 is not equal to 1.2, so the process will come to a new steady state. What is it?)

What conclusions can you draw concerning the need for accuracy in a steady-state model? For the accuracy of the measurement device?
For the accuracy of the control valve?
Consider all of these with respect to their use in a feedforward control system.