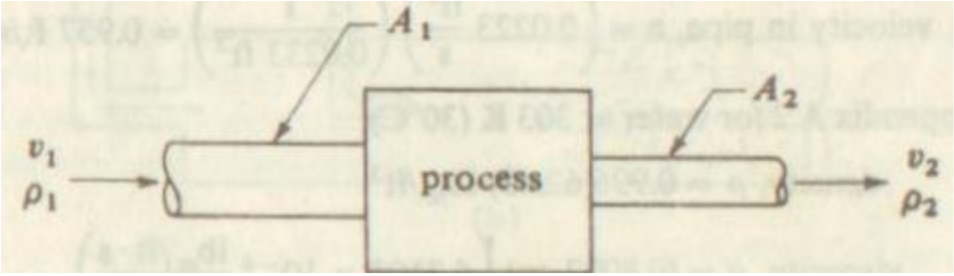
OVERALL MASS BALANCE & CONTINUITY EQUATION

- In fluid dynamics fluids are in motion.

- Generally, they are moved from place to place by means of mechanical devices such as pumps or blowers, by gravity head, or by pressure, and flow through systems of piping and/or process equipment.

- The first step in the solution of flow problems is generally to apply the principles of the conservation of mass to the whole system or to any part of the system.

- First, we will consider an elementary balance on a simple geometry, and later we shall derive the general mass-balance equation.



- Simple mass or material balances……..
- INPUT = OUTPUT + ACCUMULATION
- Since, in fluid flow, we are usually working with rates of flow and usually at steady state, the rate of accumulation is zero and we obtain

- RATE OF INPUT = RATE OF OUTPUT (at steady state)-----(Eqn.1)

- In Fig.a simple flow system is shown where fluid enters section 1 with an average velocity v_1 and density ρ_1. The cross-sectional area is A_1.
- The fluid leaves section 2 with average velocity v_2
- The mass balance, Eqn. (1), becomes

$$\boxed{\dot{m} = \rho_1 v_1 A_1 = \rho_2 v_2 A_2} \longrightarrow \textbf{Continuity Equation}$$

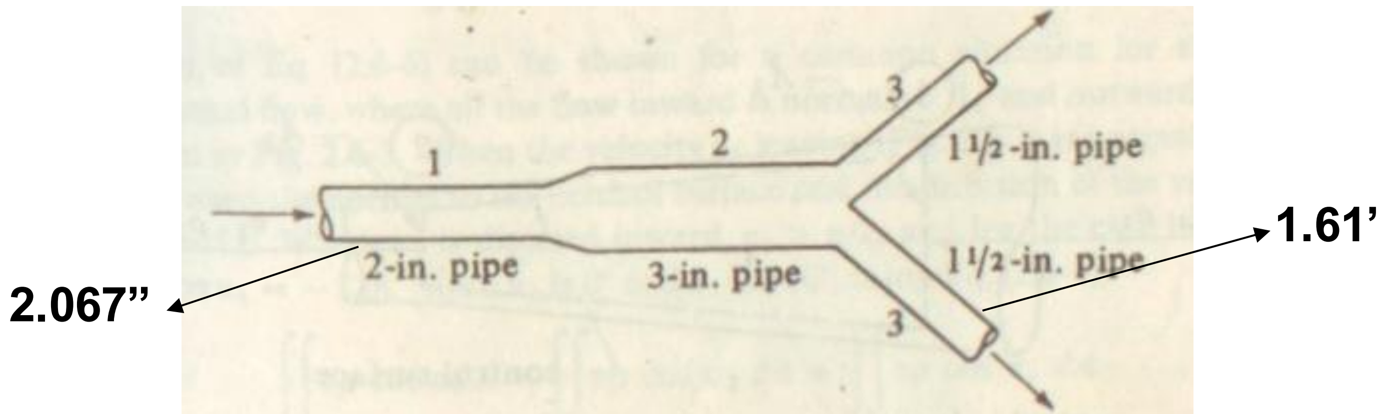
$$\boxed{\begin{gathered} if \quad \rho_1 = \rho_2 = \rho \\ \frac{\dot{m}}{\rho} \Rightarrow Q = v_1 A_1 = v_2 A_2 \end{gathered}}$$

$$\boxed{\begin{gathered} and\ldots\ldots\ldots \\ v_1 A_1 = v_2 A_2 \end{gathered}}$$

Prob 1

Flow of Crude Oil and Mass Balance

A petroleum crude oil having a density of 892 kg/m^3 is flowing through the piping arrangement shown in Fig. at a total rate of 1.388×10^{-3} m^3/s entering pipe 1.



The flow divides equally in each of pipes 3. The steel pipes are Schedule 40 pipe (see Appendix A.5 for actual dimensions). Calculate the following using SI units.

(a) The total mass flow rate in pipe 1 and 3.

(b) The average velocity v in 1 and 3.

- a). Given, Vol flowrate $Q_1 = 1.388 \times 10^{-3}\ m^3/s$

- Mass flow rate = $m_1 = \rho_1\ v_1 A_1 = 1.238$ kg/s

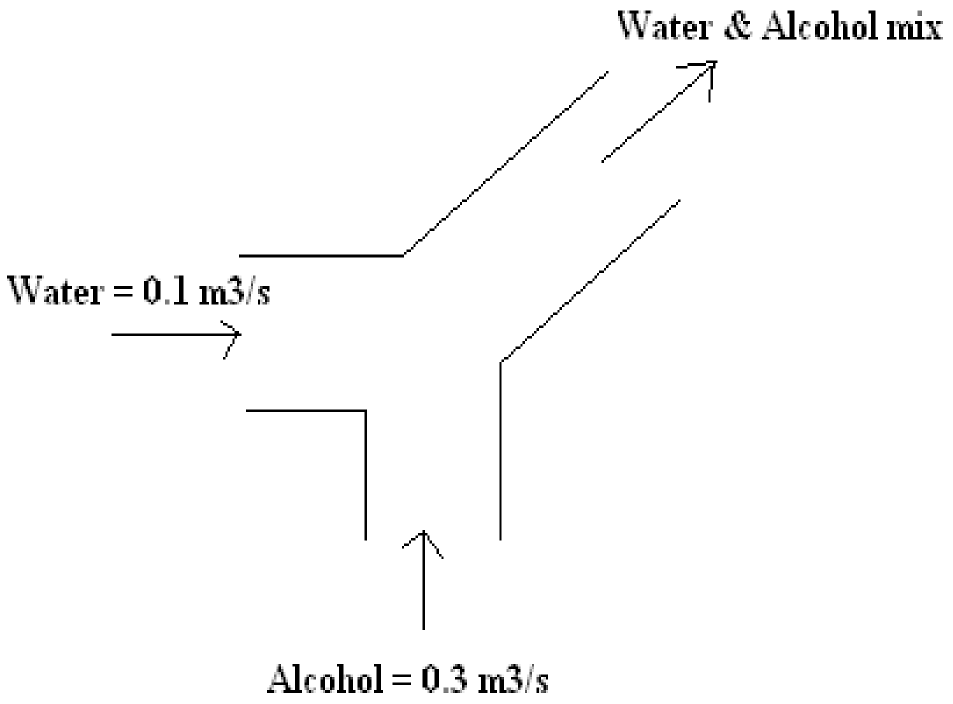
- Since flow divides equally in each of pipes 3, $m_3 = (m_1 / 2) = 0.619$ kg/s

- b). $v_1 = Q_1/A_1 = 0.641$ m/s

- and $v_3 = Q_3/A_3 = 0.528$ m/s

Prob 2

- Water at $0.1 m^3/s$ and alcohol (s.g 0.8) at $0.3 m^3/s$ are mixed in a "Y" duct as shown in fig. What is the average density of mix of alcohol and water?



- We know, $\dot{m}_1 + \dot{m}_2 = \dot{m}_3$
- Or, $Q_1 \rho_1 + Q_2 \rho_2 = Q_3 \rho_3$
- *And* $Q_1 + Q_2 = Q_3$
- Therefore, $\rho_3 = 850 \text{ kg/m}^3$