EN644 Two-Phase Flow and Heat Transfer
Assignment -3

1. (a) Consider a single phase flow of liquid, whose velocity is V, density is ρ and viscosity μ. Derive the relation that will express the frictional pressure drop over the length of pipe L, if the flow is laminar. Note that there will be no dependence on ρ.
   (b) Now let us idealize two-phase flow to be a train of alternate lumps of liquid (L_l, ρ_l, μ_l) and gas (L_g, ρ_g, μ_g) both traveling at the same velocity V. This is an idealized representation of slug flow in horizontal pipes. Now estimate the frictional pressure drop for a length L_l+L_g as done in part A. Show that this is same as that for a homogenized fluid whos viscosity will be
   $\mu = \alpha\mu_g + (1-\alpha)\mu_l$
2. Now consider the flow of steam-water mixtures of 0.001, 0.01, 0.1 and 0.9 quality at 1, 10 and 100 bar. Compare the value of μ using the formulation used in the literature as given below.

$$\mu = \alpha\mu_g + (1-\alpha)\mu_l$$
$$\frac{1}{\mu} = \frac{\alpha}{\mu_g} + \frac{1-\alpha}{\mu_l}$$
$$\frac{1}{\mu} = \frac{x}{\mu_g} + \frac{1-x}{\mu_l}$$

$$\mu = x\mu_g + (1-x)\mu_l$$
$$\mu = \frac{j_l}{j}\mu_l + \frac{j_g}{j}\mu_g$$

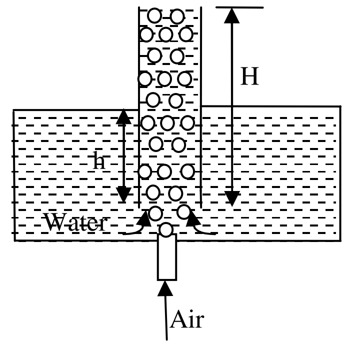
   Suitably comment on the results
3. A vertical test section is installed in an experimental high pressure loop. The tube is 1 cm in diameter and 2.1 m long and is heated uniformly with 100 kW of power. Saturated water enters at the base at 65 bar and with a flow rate of 450 kg/hr. Calculate the accelerational, frictional and gravitational pressure drop. Repeat the same at 3 bar and comment on the results obtained in terms of the magnitude of the parameters.

4. Using the basic governing equations for the homogeneous model show that the pressure gradient in the absence of shaft work can be expressed as,

$$-\frac{dp}{dz} = \frac{\dfrac{2fG^2}{d_h\rho_H} + \left(\dfrac{Gv_{fg}}{h_{fg}A}q'' - \dfrac{G^2}{A\rho_H}\dfrac{dA}{ds} + \rho_H g\sin\theta\right)\phi}{1 + \left(x\dfrac{\partial v_g}{\partial p} + (1-x)\dfrac{\partial v_l}{\partial p} + \left(\dfrac{\partial x}{\partial p}\right)_h\right)\phi}, \text{ where } \phi = \frac{1}{1 + \dfrac{G^2 v_{fg}}{h_{fg}\rho_H}}$$

Compare the order of magnitude of the various terms for vertical steam-water flow at 10% quality with $G = 5X10^6$ kg/hr-m^2 in a 2.54 cm diameter pipe with a taper of 1 in 100 at pressures of 0.1, 1 and 100 bars. Comment as to whether ϕ can be ignored (taken as 1)?

5. Figure 1 shows an air lift pump. Note that the density of the two-phase fluid inside the riser tube is lower than the fluid outside. This causes natural circulation flow. Derive an expression for the water mass flow rate in the riser tube as a function of air mass flow rate. If h = 40 cm and H = 60 cm. Plot the variation of mass flow rate of water as a function of air mass flow rate and comment on the nature of the curve. Assume water and air have properties at at 1 bar 25 ^oC. Use homogeneous model.



6. Carefully study the Bankoff's model for the explanation of the value of C_A. Obtain an expression for the same for m = n. Compute its value for m = n = 1 and 10. For what value of m will it be equal to 1. Now repeat the model for flow between two parallel plates separated from each other by a distance S. Compute the value of C_A for m equal to n as above. Rationalize your observation and comment suitably. Finally, conclude as to why there is a global slip, when there is no local slip.

7. Starting from Chisholm's postulate that $s = (v_H / v_l)^{0.5}$, show that this is equivalent to

$$s = \frac{1}{\left[1-\beta\left(1-\frac{v_l}{v_g}\right)\right]^{0.5}} \qquad (1)$$

Using basic relations, show that $\frac{\beta}{\alpha} = \beta + s(1-\beta)$ (2)

Deduce from equations (1) and (2) that $$\frac{\beta}{\alpha} = \beta + \frac{(1-\beta)}{\left[1-\beta\left(1-\frac{v_l}{v_g}\right)\right]^{0.5}}$$