Mansoura University Faculty of Engineering Dept. of Power Mech. Eng. Course Title: Multi-Phase Flow Course Code: MPE6222		POST GRAD. STUDIES September 2013 Exam Type: Final Time: 3 Hours Full Mark: 100

Answer all the following questions.

1) (a) Describe with drawing the operation principles of the two-phase air compressor
[5 Marks]

(b) Beginning from the continuity equations for the liquid and the gas, prove that

$$U_G = G[xv_G + K(1-x)v_L] \quad \text{and} \quad U_L = \frac{G}{K}[xv_G + K(1-x)v_L]$$

where U_G, G, x, v_G, K, v_L and U_L are the gas velocity, the mass velocity, the dryness fraction, the gas specific volume, the velocity ratio, the liquid specific volume and the liquid velocity, respectively. [5 Marks]

(c) Prove that

$$\rho_H = 1 / [(x)/\rho_G + (1-x)/ \rho_L]$$

where ρ_H, ρ_G, ρ_L and x are the homogeneous density, the gas density, the liquid density and the dryness fraction. [5 Marks]

(d) Liquid and gas flow in a 2 in. pipe. The values of the gas flow rate, the velocity ratio and the gas cross-sectional ratio (α) are 0.071 m^3/sec, 11.2 and 0.4, respectively. Evaluate:

(i) The phase velocities and homogeneous velocity.
(ii) The slip velocity.
(iii) The superficial phase velocities.
(iv) The dryness fraction (x).
(v) The mixture density and the homogeneous density.
(vi) The single phase friction pressure gradients Dp_{FL0}, Dp_{FL}, Dp_{FG0} and Dp_{FG}. Take the single phase friction factor as $\lambda=0.19/Re^{0.2}$.
(vii) The multipliers φ^2_{FL0}, φ^2_{FL}, φ^2_{FG0}, φ^2_{FG0} taking the two-phase pressure gradient due to friction as 900 mbar/m.
(viii) The physical property coefficient (Γ) and the normalized two-phase multiplier.

The physical properties are:

$v_G = 0.84$ m^3/kg
$v_L = 1*10^{-3}$ m^3/kg
$\mu_G = 1.789*10^{-5}$ N.sec/m^2
$\mu_L = 1.002*10^{-3}$ N.sec/m^2 [20 Marks]

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2) (a) Discuss briefly the generalized (separated, dispersed and mixed) flow patterns for different fluid types. [5 Marks]

(b) Describe with drawing the flow patterns that can be occurred in vertical gas-solid flows in a circular duct. [5 Marks]

(c)- Describe with drawing the flow patterns that can be occurred in horizontal gas-liquid-liquid three phase flows in a circular duct. [5 Marks]

(d) Saturated steam enters a 40 mm pipe with a mass velocity of 200 kg/m^2s and a pressure of 60 bars. Evaluate the pressure drop due to the momentum forces where:

1. the vapor is entirely condensed in the pipe.
2. the exit dryness fraction is 0.5 and the exit void fraction is 0.2.

The physical properties are

$v_G=32.4*10^{-3}\ m^3/kg$ and $v_L=1.3*10^{-3}\ m^3/kg$ [15 Marks]

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3) (a) Discuss briefly how the momentum flux can be measured. Also, evaluate the value of the velocity ratio at which the momentum flux will have its minimum value. [5 Marks]

(b) Specify the limitations of the Homogenous Flow Model. [5 Marks]

(c) Using the homogeneous theory and assuming that $\mu_{TP} = \mu_L$, prove that:

$$\varphi_{FL0} = \left[1 + \left(\frac{v_G}{v_L} - 1\right)x\right]$$

where μ_{TP}, μ_L, φ_{FL0}, v_G, v_L and x are the two-phase viscosity, the liquid viscosity, the two-phase multiplier, the gas specific volume and the liquid specific volume and the dryness fraction, respectively. [5 Marks]

(d) Two phase mixture of saturated steam and water is flowing in a vertical adiabatic pipe with 50 mm internal diameter and 3.5 m in length. Calculate the friction, gravity and momentum pressure drop in the pipe if the inlet mass velocity of steam and water are 500 and 700 $kg/m^2.s$, respectively. Assume constant properties at reference pressure p = 7 Mpa. The values of the void fraction, λ_{L0} and λ_{G0} are 0.2, 0.025 and 0.015, respectively.

Where $\varepsilon/D=0.002$ and
$$B_s = \begin{cases} \dfrac{21\Gamma - 2^{2-n} + 2}{\Gamma^2 - 1} & \text{when } \Gamma \succ 8.9 \\ 2^{2-n} - 1 & \text{when } \Gamma \prec 8.9 \end{cases}$$

$$\varphi^2_{FL0} = 1 + \left(\Gamma^2 - 1\right)\left[Bx^{(2-n)/2}(1-x)^{(2-n)/2} + x^{2-n}\right]$$

$$\frac{B_R}{B_S} = \left[0.5\left\{1 + \left(\frac{\mu_G}{\mu_L}\right)^2 + 10^{-600\varepsilon/D}\right\}\right]^{(0.25-n)/0.25}$$

where B_R and B_S and n are the B coefficient parameter for rough and smooth pipes, respectively. n is the Blasius equation exponent.

The physical properties at reference pressure = 7 Mpa are

$v_G = 32*10^{-3}$ m^3/kg, $v_L = 1.0*10^{-3}$ m^3/kg , $\mu_L = 100*10^{-6}$ $N.s/m^2$ and $\mu_G = 20*10^{-6}$ $N.s/m^2$

Also, compare the total pressure drop with single-phase flow case, if:

- Only saturated water with $G = 1200$ $kg/m^2.s$ was flowing in the same pipe,
- Only saturated steam with $G = 1200$ $kg/m^2.s$ was flowing in the same pipe. [20 Marks]

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