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M.E. MECHANICAL ENGINEERING FIRST YEAR SECOND SEMESTER EXAMINATION, 2018

MASTER OF NUCLEAR ENGINEERING FIRST YEAR SECOND SEMESTER EXAMINATION, 2018

Two Phase Flow, Boiling and Condensation

Time: 3 hours | Full Marks: 100

Use *separate* answer script for each part.

Part-I

Attempt all questions

(Symbols denote their usual meaning)

1. Answer any ***three*** parts (7x3=21)

a) What do you mean by contact angle and apparent contact angle? What is the role of apparent contact angle in vapour nucleus formation and growth?

b) Draw pool boiling curve. Why at ONB there is a drop in wall temperature for water under atmospheric pressure?

c) What do you mean by critical heat flux? Show that critical heat flux is expressed as

$$q_{crit} = Kh_{fg}\left[\sigma g\left(\rho_f - \rho_g\right)\right]^{1/4}$$

d) Explain bubble agitation, boundary layer stripping and microlayer evaporation in connection with nucleate boiling.

2. Show that for a vertical surface under constant temperature condition, the scale of heat transfer co-efficient for film boiling condition is given by the following:

$$h \sim \left[\frac{g\left(\rho_l - \rho_g\right)\rho_g k_g^3 h_{fg}}{L\mu_g \Delta T_{sat}}\right]^{1/4} \qquad (15)$$

Or

2. Subcooled water enters a vertical tube under constant heat flux condition. Show different flow regime and temperature distribution of wall and fluid. (15)

3. Show that modification of the condensation theory yields the following expression of net condensation mass flux-

$$j = \left(\frac{2\sigma}{2-\sigma}\right)\left(\frac{M}{2\pi R}\right)^{1/2}\left[\frac{p_g}{T_g^{1/2}} - \frac{p_f}{T_f^{1/2}}\right] \qquad (14)$$

Part - II

Answer any TWO questions

All parts of the same question must be answered together.

Q:1(a) Derive Reynolds Transport Theorem for a control volume containing a discontinuity. 18

(b) Use the above result to derive the expression for mass conservation across an interface between two phases. 7

Q:2(a) State the basic assumptions of separate cylinder model. Derive the separate cylinders model for turbulent flow, assuming a constant friction factor for both phases. 15

(b) Write the continuity, momentum and energy equations for separated flow model. Show that for separated flow $G = \rho_1 v_1 \dfrac{1-\alpha_2}{1-x_2} = \rho_2 v_2 \dfrac{\alpha_2}{x_2}$ where the symbols have usual meaning. 10

Q:3 a) Assuming the following expression for the pressure gradient of a homogeneous steady one-dimensional two phase flow

$$-\frac{dp}{dz} = \frac{\dfrac{2C_f}{D} G^2(v_1 + xv_{12}) + G^2 v_{12}\dfrac{dx}{dz} - G^2(v_1 + xv_{12})\dfrac{1}{A}\dfrac{dA}{dz} + \dfrac{gSin\theta}{v_1 + xv_{12}}}{1 + G^2\left[x\dfrac{dv_2}{dp} + (1-x)\dfrac{dv_1}{dp}\right]}$$

where the symbols have usual meaning, deduce the expression for velocity of sound in a two-phase medium in terms of velocities of sound in the components and volume fraction of the components. Show that in the limit of $\rho_1 >> \rho_2$ and $\rho_1 c_1^2 >> \rho_2 c_2^2$, the velocity of sound in two phase medium can be expressed as

$$c^2 = \frac{\rho_2}{\rho_1}\frac{c_2^2}{\alpha(1-\alpha)}$$ 15

b) Show that for a single particle, the terminal Reynolds number, Re_∞ satisfies the relation $C_D \text{Re}_\infty^2 = \frac{4}{3} Gr$ 10

Q:4(a) Show a schematic graphical representation of the functional dependence between drift flux and void fraction. Also, show on the figure the regimes of cocurrent and counter-current flow and no solution. 9

(b) What is flooding point? For a functional dependence of drift flux on void fraction of the form $j_{21} = \alpha(1-\alpha)^n v_\infty$, derive the expressions for j_1 and j_2 at the flooding point. 8

(c) Define the following terms: (a) volume fraction (b) mass fraction (c) drift flux (d) mass flux 8