Ex/ChE/T/414C/2019

B.E. CHEMICAL ENGINEERING FOURTH YEAR FIRST SEMESTER 2019

ADVANCED FLUID DYNAMICS

Time: Three hours *Full marks: 100*

This paper contains three modules. Answer ***any two questions from module 1, any one question from module 2 and the compulsory question from module 3****. Assume any missing data.*

MODULE 1: Answer any two questions

1. (a) State whether the following can represent irrotational flow.

   (i) $\psi = \left(r - \frac{2}{r}\right)\sin\theta$

   (ii) $\psi = 2\ln\left(\frac{x}{2y}\right)$

   (b) The discharge of 50 m^3/s effluent from a plant into a 10 m deep river flowing at 0.2 m/s can be modeled as a 2-D source spanning across the river depth. It is found that the fish and other aquatic life in a certain zone of the river die out, whereas those outside it are almost unaffected. The discharge is located in the middle of a wide river. You are asked to obtain the extent of this critical region.

   (i) How will you model this system by superposition of simple potential flows? Obtain the complex potential for the flow, the stream function and the stagnation point.

   (ii) Obtain the extent of the critical region.

   (5+4)+(10+4)

2. (a) A spiral vortex is a good model for the flow around the core of a stationary tornado. How would you obtain a spiral vortex by superposition of simple potential flows?

   (b) In a typical stationary tornado, the pressure is found to be 720 Pa below atmospheric at a radial distance of 220 m from its centre and the influx of air is 25×10^3 m^3/s per meter height.

   Obtain an expression for the variation of pressure with radial location for the outer region of the tornado considering that the spiral vortex model is valid. Find the sink and the vortex strengths, the radial velocity at 220 m from the centre and the pressure at 300 m from the centre. 5+18

3. (a) How will you represent flow past a circular cylinder without circulation by superposition of simple potential flows? Obtain the stream function and the velocity potential and locate the stagnation points.

   (b) Can you explain drag force on a cylinder using this irrotational flow model?

   (c) What is Kutta-Zhukhovsky lift theorem? 12+5+6

[Turn over

MODULE 2: Answer any one question

4. (a) Gas and oil are flowing at volumetric flow rates 10 ft^3/s and 0.025 ft^3/s in a horizontal pipeline of internal diameter D = 0.5 ft. The physical properties are gas density: 0.15 lbm/ft^3, liquid density: 50 lbm/ft^3, gas viscosity 0.025 lbm/ft hr, liquid viscosity 20 lbm/ft hr. Note that for laminar pipe flow Fanning friction factor $F_f = 16/Re$ and for turbulent pipe flow $F_f = 0.0045$.
   (i) Estimate the fraction of gas, the pressure gradient and the mean velocities of each phase using the Lockhart and Martinelli parameters attached.
   (ii) Also obtain the fraction of gas assuming homogeneous flow model to be valid and comment on your result.

   (b) Sketch and name different flow patterns in horizontal and vertical two phase flows.

   18+4+8

5. (a) Derive an expression for predicting pressure gradient for homogeneous flow of a boiling liquid in a round tube of constant diameter D with a uniform heat flux φ, liquid and vapor phase specific volumes v_f and v_g, quality x, mass flux G, inclination of the duct to the vertical θ, specific enthalpy of liquid phase h_f and that of vapor phase h_g. Neglect kinetic and potential energy terms and the effects of flashing and compressibility. Assume a constant friction factor C_f. Also express quality at a particular distance from the inlet when the inlet quality is given as x_i.

   (b)Sketch approximate sequence of flow patterns in a vertical tube evaporator.

   24+6

MODULE 3: Answer the compulsory question

6. Show that $\frac{\partial}{x} = \frac{5.48}{\sqrt{Re_x}}$ for a boundary layer over a flat plate using von Karman's method of approximate solution.
   Sketch the non-dimensional velocity profile for your solution. Also sketch the Blasius profile in the same plot.

   20+4

	Void	*Liquid:*	*Turb*	*Visc*	*Turb*	*Visc*
	Fraction	*Gas:*	*Turb*	*Turb*	*Visc*	*Visc*
X	ε		ϕ_g	ϕ_g	ϕ_g	ϕ_g
0.01			1.28	1.20	1.12	1.05
0.02			1.37	1.28	1.16	1.07
0.04			1.54	1.36	1.24	1.12
0.07	0.96		1.71	1.45	1.35	1.19
0.1	0.95		1.85	1.52	1.45	1.24
0.2	0.91		2.23	1.78	1.74	1.40
0.4	0.86		2.83	2.25	2.20	1.70
0.7	0.81		3.53	2.85	2.85	2.16
1.0	0.77		4.20	3.48	3.48	2.61
2.0	0.69		6.20	5.25	5.24	4.12
4.0	0.60		9.50	8.20	8.60	7.00
7.0	0.52		13.7	12.1	12.8	11.2
10.0	0.47		17.5	15.9	16.6	15.0
20.0	0.34		29.5	28.0	28.8	27.3
40.0	0.24		51.5	50.0	50.0	50.0
70.0	0.16		82.0	82.0	82.0	82.0
100.0	0.10		111.0	111.0	111.0	111.0

Table 10.4 Values from Lockhart and Martinelli

	n	*Liquid Flow*	*Gas Flow*
	4.12	Turbulent	Turbulent
	3.61	Viscous	Turbulent
	3.56	Turbulent	Viscous
$X < 1$:	2.68	Viscous	Viscous
$X > 1$:	3.27	Viscous	Viscous

Table 10.5 Exponents for Two-Phase Correlation