Multiphase flows:Analytical solutions and Stability Analysis - Video course

COURSE OUTLINE

This course concentrates on obtaining analytical and semi-analytical solutions to multiphase flow problems. The emphasis is on using a very fundamental approach : equations of conservation of mass, momentum and energy without any empiricism. The focus is on getting approximate solutions using perturbation theory, and analysing stability of systems using linear stability analysis. This will help prepare students for doing research in these areas.

COURSE DETAIL

Lec No	Topic
1	Introduction and overview of the course: Multiphase flows
2	Stratified flow in a micro channel: Velocity profiles.
3A	Stratified flow in a micro channel: Effects of physical parameters
3B	Flow regimes in microchannels: Modeling and Experiments
4	Scaling Analysis: Introduction
5	Scaling Analysis: Worked Examples
6	Interfacial tension and its role in Multiphase flows
	Eulerian and Lagrangian approaches

NPTEL

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Chemical Engineering

Pre-requisites:

It is desirable to have done a first course on Fluid Mechanics, and have Exposure to Partial Differential Equations, Fourier series and Linear Algebra. Proficiency in programming in Matlab will be useful.

Coordinators:

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8	Reynolds Transport Theorem and the Equation of Continuity
9	Derivation of Navier-Stokes equation
10	Vector operations in general orthogonal coordinates: Grad., Div., Lapacian
11	Normal and shear stresses on arbitrary surfaces: Force balance
12	Normal and shear stresses on arbitrary surfaces: Stress Tensor formulation
13	Stresses on deforming surfaces: Introduction to Perturbation Theory
14	Pulsatile flow: Analytical solution
15	Pulsatile flow: Analytical solution and perturbation solution for Rw<<1
16	Pulsatile flow: Perturbation solution for Rw >> 1
17	Viscous heating: Apparent viscosity in a viscometer
18	Domain perturbation methods: Flow between wavy walls
19	Flow between wavy walls: Velocity profile
20	Introduction to stability of dynamical systems: ODEs
21	Stability of distributed systems (PDEs): reaction diffusion example
22	Stability of a reaction-diffusion system contd.

23	Rayleigh-Benard convection: Physics and governing equations	
24A	Rayleigh-Benard convection: Linear stability analysis part 1	
24B	Rayleigh-Benard convection: Linear stability analysis part 2	
24C	Rayleigh-Benard convection: Linear stability analysis part 3	
25	Rayleigh Benard convection: Discussion of results	
26	Rayleigh-Taylor ‘heavy over light’ instability	
27	Rayleigh-Taylor instability contd.	
28	Capillary jet instability: Problem formulation	
29	Capillary jet instability: Linear stability analysis	
30	Capillary jet instability: Rayleigh’s Work Principle	
31	Tutorial Session: Solution of Assignment 4 on linear stability	
32	Turing patterns: Instability in reaction-diffusion systems	
33	Turing patterns: Results	
34	Marangoni convection: Generalised tangential and normal stress boundary conditions	
35	Marangoni convection: Stability analysis	
36	Flow in a circular curved channel: Governing equations and scaling	

37	Flow in a circular curved channel: Solution by regular perturbation
38	Stability of flow through curved channels: Problem formulation
39	Stability of flow through curved channels: Numerical calculation
40	Viscous Fingering: Darcy's law
41	Viscous Fingering: Stability analysis
42	Shallow Cavity flows

References:

Textbooks

1. Leal, L.G (2008). Advanced transport phenomena: Fluid mechanics and convective transport processes. Cambridge: Cambridge University Press.

Reference Books

1. Krantz, W. B (2007). Scaling analysis in modeling transport and reaction processes. A Systematic Approach to Model Building and the Art of Approximation. New Jersey: John Wiley and Sons Inc.
2. Pierre-Gilles de Gennes, Francoise Brochard-Wyart, David Quere (2003). Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls, Waves. New York: Springer Science Business Media Inc.
3. White, F.M (1991). Viscous Fluid Flow (third edition). Tata Mcgraw Hill
4. Rutherford, A. (1990). Vectors, Tensors and the Basic Equations of Fluid Mechanics. Dover Publications Inc.
5. Gupta, V., Gupta, S.K (1984). Fluid Mechanics and Its Applications. Wiley Eastern
6. Newell, H. E (2008). Vector Analysis. Dover publications.
7. Van Dyke, M. (1975). Perturbation Methods In Fluid Mechanics. Stanford, California: The Parabolic Press
8. Johns, L. E., & Narayanan, R. (2002). Interfacial Instability. New York: Springer-Verlag.
9. Pushpavanam, S. (2012). Mathematical Methods for Chemical Engineers (Reprint ed.). PHI Learning Pvt.
10. Strogatz, S. (2000). Nonlinear dynamics and chaos with applications to physics, biology, chemistry, and engineering. Cambridge, MA: Westview Press.

11. Cross, M., & Greenside, H. (2009). Pattern formation and dynamics in nonequilibrium systems. Ch.2.Cambridge, UK: Cambridge University Press
12. Chandrasekhar, S. (1961). Hydrodynamic and hydromagnetic stability. Oxford University Press.
13. Drazin, P. G., Reid, W. H. (2004). Hydrodynamic Stability (2nd Ed. p.108). New York: Cambridge University Press.

Journal publications

1. B. Malengier, S. Pushpavanam, Comparison of Co-Current and Counter-Current Flow Fields on Extraction Performance in Micro-Channels, Adv. Chem. Eng. Sci. 02 (2012) 309–320.
2. A.B. Vir, S.R. Kulkarni, J.R. Picardo, A. Sahu, S. Pushpavanam, Holdup characteristics of two-phase parallel microflows, Microfluid. Nanofluidics. (2013).
3. Joseph, D. D. Domain perturbations: the higher order theory of infinitesimal water waves. Arch. Rational Mech. Anal. 51 (1975) 295–303.
4. A.M. Turing. The Chemical Basis of Morphogenesis, Philos. Trans. R. Soc. Lond. B. Biol. Sci. 237 (2007) 37–72
5. Dean, W. R. Note on the motion of fluid in a curved pipe. Phil. Mag., 4(1927), 208–223
6. Sparrow, E. M. On the onset of flow instability in a curved channel of arbitrary height. ZAMP. 15(1964) 638–642