Incompressible Flow (MANE-6560)

Department of Mechanical, Aerospace, and Nuclear Engineering, RPI

Spring 2020; M,Th 12:00 – 1:20 PM, RI-212

This is a graduate-level course in hydrodynamic theory, covering classical classical and modern theories. The course will cover topics that were developed long ago in part by Helmholtz, Kelvin, Prandtl, Rayleigh, Stokes and others, and in which significant advances have been made during the past three decades. The course will attempt to provide a physical understanding of various mechanisms that play a major role in hydrodynamics. Topics include surface waves along with a general description of interfacial phenomena including capillarity and Marangoni flow, hydrodynamic instabilities, and vortex dynamics.

Instructor: Prof. Amir H. Hirsa, JEC 5036, 276-6997, hirsaa@rpi.edu Office Hours: Tuesdays 5-6 PM.

Text:	No required texts; see below for list of some useful references	
Prerequisites:	At least one course dedicated to fluid dynamics	
Grading:	Exam I (1.5 h, open book/notes, Mon. Feb. 24)	25%
	Exam II (Mon. Apr. 6)	25%
	Final Exam (2 h, Mon. Apr. 27)	30%
	Homework	20%

Homework Policy: Turn in homework in class on the day it is due. Late homework: half credit if less than one week late.

Course Outline:

1) Surface Waves and Interfacial Phenomena
   a. Introduction to waves
   b. Linear dispersive waves (deep water gravity waves, surface tension and capillary waves, and capillary-gravity waves)
   c. Group velocity
   d. Non-dispersive waves (shallow water waves)
   e. Weakly nonlinear waves
   f. Interfacial phenomena, including surface elasticity (Marangoni effect), surface viscosity and other viscous effects (note, general boundary conditions at fluid interfaces – gas/liquid or liquid/liquid – will be described with application to wave dampening)
2) Flow Instability
   a. Capillary instability: Break-up of liquid jets (Rayleigh instability)
   b. Thermal instabilities (Benard and Benard-Marangoni instability)
   c. Centrifugal instabilities: Flow between rotating cylinders (Rayleigh criteria and the Taylor-Couette instability)
   d. Viscous instability (Poiseuille flow)
3) Vortex Dynamics
   a. Vortex laws and flow invariants
   b. Generation and decay of vorticity
   c. Vortex flows (including vortex pairs, vortex rings, and Karman vortex streets)
   d. Vortex-boundary interactions
   e. Vortex instabilities

Primary References:

1) Lighthill, 1978 Waves in Fluids Cambridge University Press
2) Edwards, Brenner & Wasan 1991 Interfacial Transport and Rheology Butterworth-Heinemann
3) Drazin & Reid 1981 Hydrodynamic Stability Cambridge University Press
4) Lugt, 1996 Introduction to Vortex Theory Vortex Flow Press