MENG 463 / ENAS 704: THEORETICAL FLUID DYNAMICS
FALL 2010

Instructor:

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Course Website:

http://leviathan.eng.yale.edu/teaching/meng463/

Lectures:

MWF 10:30-11:20, Becton 508

Office Hours:

T Th 11:00-12:00, or by appointment.

Textbooks:

Required:
P. K. Kundu & I. M. Cohen, *Fluid Mechanics*, 4th edition

Useful references (on reserve in library):
G. K. Batchelor, *An Introduction to Fluid Dynamics*
D. J. Tritton, *Physical Fluid Dynamics*
L. D. Landau & E. M. Lifshitz, *Fluid Mechanics*
S. B. Pope, *Turbulent Flows*, Appendix A (electronic reserve)

Grading:

Weekly problem sets	(20%)
Mid-term exam (take-home)	(35%)
Final exam (take-home)	(45%)

Course Outline

1. **Fundamentals and Kinematics** (Kundu & Cohen, chapters 1 & 3)

   Definitions; continuum hypothesis; fluid statics; Eulerian and Lagrangian frameworks; material lines and volumes; material derivatives; forces and the stress tensor.

2. **Mathematical Tools** (Kundu & Cohen, chapter 2)

   Cartesian tensors and pseudotensors; tensor formulation of integral theorems of vector calculus; Reynolds transport theorem.

3. **Conservations Laws and Equations of Motion** (Kundu & Cohen, chapter 4)

   Mass conservation and continuity; momentum equation; velocity gradients; Newtonian fluids; Navier-Stokes and Euler equations; Reynolds number; energy and entropy equations; Bernoulli's equation; boundary conditions.

4. **Vorticity Dynamics** (Kundu & Cohen, chapter 5)

   Vorticity equation; Kelvin's theorem; Helmholtz's theorem; vortex stretching; vorticity production; Biot-Savart law; two-dimensional flow; streamfunction-vorticity formulation.

5. **Potential Flow** (Kundu & Cohen, chapter 6)

   Irrotational, inviscid flow; potential flow equations; Helmholtz decomposition; irrotational vortices.

6. **Viscous Flow** (Kundu & Cohen, chapter 9)

   Stokes flow; creeping flow over a sphere; Rayleigh's problem; self-similarity; role of the Reynolds number.

7. **Boundary Layers** (Kundu & Cohen, chapter 10)

   Boundary-layer equations; boundary-layer thickness; Blasius and Falkner-Skan solutions; separation.

8. **Introduction to Compressible Flow** (Kundu & Cohen, chapter 16)

   Mach number; weak compressibility; normal shocks.

9. **Introduction to Geophysical Fluid Dynamics** (Kundu & Cohen, chapters 7 and 14)

   Navier-Stokes equations in a rotating frame; Rossby number; Taylor-Proudman theorem; density stratification; Boussinesq approximation; waves; geostrophic flow.

10. **Introduction to Hydrodynamic Stability** (Kundu & Cohen, chapter 12)

    Normal modes; Rayleigh-Bénard instability; Kelvin-Helmholtz instability; Orr-Sommerfeld equation.

11. **Introduction to non-Newtonian Fluid Mechanics**

    Viscoelasticity; shear thinning and thickening; constitutive models; rheology.