

Fluid Mechanics

The field of fluid mechanics, as it relates to preparation for the Ph.D. degree in Mechanical Engineering or Aerospace Engineering, is concerned with the study of all aspects of fluid motion relevant to the areas of mechanical and aerospace engineering.

Summary of Major Field Body of Knowledge:

Students should master the major field body of knowledge covered in the following courses:

MAE 150A, 150B, 250A, 250B, 250C

and a selection of 3 courses from:

MAE 250D, 250E, 250F, C250G, 250M, 252A, 252B, 252C, 252P, 259A.

The written qualifying (preliminary) examination covers the following subset of the major field body of knowledge:

MAE 150A, 150B, 250A, 250B, 250C.

More details concerning the major field body of knowledge can be found in the **Syllabus for the Major Field**, on the next page.

Minimum Requirements for Ph.D. Major Field Students:

The student must pass a written examination in the major field and satisfy other program requirements for the Ph.D. in the MAE Department besides completing all other formal University requirements.

Format of Written Qualifying Examination:

The exam consists of a 4-hour closed book part and a 3-hour open book part, followed by an oral exam.

Timing of Written Qualifying Examination:

Offered every fall.

Link to old exams:

<http://stdntsvcs.mae.ucla.edu/exam/index.htm>

Ph.D. Minor Field Requirements:

Ph.D. minor field requirements in fluid mechanics may be satisfied by completion of MAE 250A and two other courses chosen from the list given below. The student should obtain grades of B or better, with at least one A. Two of the courses must be graduate courses. The courses should not form part of any other major field requirement.

MAE 150B, 150P, 153A, 157A, 250B, 250C, 250D, 250E, 250F, C250G, 250M, 252A, 252B, 252C, 252P, 259A.

Note that MAE 150A is not included as part of the PhD minor field in Fluid Mechanics.

The student should consult with a major field advisor or with one of the members of the Fluid Mechanics Field Committee concerning suitability of the courses taken. The student should be able to defend the choice on the basis of learning experience and not on the basis of convenience.

As prerequisite to the minor field, the student should be familiar with the material covered in MAE 103 (Elementary Fluid Mechanics) and MAE 150A (Intermediate Fluid Mechanics); please see course outlines for details.

Syllabus for the Major Field in Fluid Mechanics

I. Written Examination: Parts I and II

All Ph.D. major field students should be familiar with important basic as well as advanced concepts, methods, and applications related to the following material and should be ready to apply their knowledge to traditional as well as novel and interrelated physical situations.

A. Conservation equations

1. Physical properties of fluids [1-4] [150AB,250A,250C]
2. Kinematics of fluid motion and the constitutive equations [2-6] [150A,250A]
3. Integral (global) form of conservation equations (mass, momentum, energy) and applications [1,2] [150AB]
4. Differential form of conservation equations (continuity, Navier-Stokes equations, energy equation) [2-4,7,8] [150A,250A,250C]
5. Dimensionless parameters, dimensional analysis, and dynamic similitude [1,2] [150A,250A]

B. Flow of effectively inviscid, incompressible fluids

1. Concept of vorticity, circulation; Kelvin's theorem [2-5] [150A,250A]
2. Vorticity dynamics, Kelvin and Bjerknes theorems, Helmholtz vorticity theorem, flows with concentrated and distributed vorticity [3-5] [250A]
3. Steady and unsteady Bernoulli equation [2,3] [150AB,250A]
4. Irrotational flow of an incompressible fluid:
 - a. Two and three-dimensional potential flow theory, superposition of solutions, complex potential, Blasius theorems, conformal transformations [1-4] [150AB,250A]
 - b. Calculation of forces on bodies, Kutta-Joukowski theorem of lift, elements of airfoil and wing theory (Kutta condition, pressure drag, induced drag, panel methods), concept of virtual mass [1-4,9] [150AB,250A]

C. Flow of incompressible viscous fluids

1. Exact solutions of the Navier-Stokes equations, e.g. plane and circular Couette and Poiseuille flows, impulsive and oscillatory motion of an infinite flat plate, stagnation point flow, flow due to a rotating disk [2,3,10] [150A,250AB]
2. Viscous flows with low inertia: 2D lubrication theory and journal bearings, Stokes flow about a sphere, Oseen approximation, Hele-Shaw flow [3,10] [150A,250B]
3. Laminar boundary layer theory: Prandtl approximation, Blasius flat plate solution, Falkner-Skan similarity solutions, momentum integral techniques, Mangler transformation, unsteady boundary layers, separation [3,10] [150A,250B]
4. Flow instability: Kelvin-Helmholtz instability, boundary layer instability (Orr-Sommerfeld equation), transition to turbulence [3,6,10] [250B]
5. Turbulent flows: concept of Reynolds stress, mean flow equations, Prandtl mixing length theory, turbulent boundary layers, drag and resistance laws, law of the wall, law of the wake, turbulent jets, wakes, and shear layers, Kolmogorov hypotheses [2,3,6,10,11] [150A,250B]

D. Compressible flow

1. Steady, one-dimensional gas dynamics: isentropic flow, flow with heat addition or friction, normal shock waves [1,2,8,12] [150AB,250C]
2. Unsteady, 1D gas dynamics: characteristic equations and the method of characteristics, weak shocks [5,7,8] [250C]
3. Steady, two-dimensional gas dynamics: oblique shocks, supersonic expansion and isentropic compression (Prandtl-Meyer function), shock-expansion theory, linearized potential flow: thin airfoil theory, 2D method of characteristics [7,8,12] [150B,250C]
4. Viscous compressible flows: compressible Couette flow, laminar and turbulent compressible boundary layers [5,8,12] [250C]

II. Course Preparation

As preparation for the written examinations, it is recommended that the major field student in fluid mechanics take the MAE 250ABC courses. The student should also be familiar with the material covered in the prerequisites to these courses (MAE 150A, 150B, 182A, and 182B).

In addition to passage of both parts of the major field examination, the Ph.D. student in fluid mechanics is expected to take three advanced, specialized courses in the field. The student should obtain a grade point average of at least 3.33 in these courses. These courses should reflect an interest in a coherent group of subjects within fluid mechanics (which may be directly related to the student's intended area of Ph.D. research). These three courses should be chosen by the student in consultation with his or her advisor or a member of the Fluid Mechanics major field committee, and normally should be completed within the first two years of the student's graduate education. Possible courses include: MAE 250D, 250E, 250F, C250G, 250M, 252A, 252B, 252C, 252P, 259A.

References:

The following books have been referred to in the description of the syllabus. Other books, recommended by a faculty member, might also be consulted. The latest editions of the following texts are the most relevant.

- [1] Wilcox, D., **Basic Fluid Mechanics**, DCW Industries.
- [2] Sabersky, R. H., Acosta, A. J., and Hauptmann, E. G., **Fluid Flow**, Macmillan Co.
- [3] Panton, R. L., **Incompressible Flow**, Wiley-Interscience.
- [4] Kundu, P. K., Cohen, I. M., and Dowling, D. R., **Fluid Mechanics**, Academic Press.
- [5] Landau, L. D., and Lifshitz, E. M., **Fluid Mechanics**, Pergamon Press.
- [6] Currie, I. G., **Fundamental Mechanics of Fluids**, CRC Press.
- [7] Thompson, P. A., **Compressible Fluid Dynamics**, McGraw-Hill.
- [8] Anderson: J. D., **Modern Compressible Flow**, McGraw-Hill.
- [9] Anderson, J. D., **Fundamentals of Aerodynamics**, McGraw-Hill.
- [10] Schlichting: H., **Boundary Layer Theory**, McGraw-Hill.
- [11] White, F. M., **Viscous Fluid Flow**, McGraw-Hill.
- [12] Liepmann, H. W. and Roshko, A., **Elements of Gas Dynamics**, John Wiley and Sons.