PHY 336L: FLUID MECHANICS: FALL 2021

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Overview

Fluid mechanics is one of the oldest branches of physics. In fact, one third of Newton's *Principia* was devoted to fluid statics. Moreover, the basic principles of fluid dynamics were formulated by scientists such as Euler, D. Bernoulli, and d'Alembert in the first half of the 18th century. Unlike the governing equations of electromagnetism and quantum mechanics, which are linear, the governing equations of fluid mechanics are *nonlinear.* This nonlinearly has profound consequences, because it implies that fluid mechanics is not scale-invariant. Indeed, fluid mechanics on small spatial scales is fundamentally different to that on large spatial scales, because the former is dominated by viscosity, and the latter is dominated by inertia. At first sight, fluid mechanics on human scales falls into the latter class, and initially lead scientists to explore it by completely neglecting viscosity. However, this approach led to the paradoxical prediction that a flowing fluid could exert no net force on an obstacle in its path. This paradox is known as *d'Alemert's paradox*, and was fully appreciated in the 18th century. However, the paradox was not resolved until the early 20th century by the boundary layer theory of Prandtl.

This aim of this course is to investigate fluid mechanics by first formulating the viscosity-free version of the theory, and showing how it leads to d'Alembert's paradox, and then explaining how this paradox can be resolved by means of boundary layer theory. The course will also investigate the theory of both subsonic and supersonic flight.

Topics to be Covered in Course

- Mathematical Models of Fluid Motion
- Hydrostatics
- Incompressible (i.e., subsonic) Inviscid Flow
- Two-Dimensional Incompressible Inviscid Flow
- Two-Dimensional Potential Flow
- Axisymmetric Incompressible Inviscid Flow
- Incompressible Boundary Layers
- Incompressible Aerodynamics
- Incompressible Viscous Flow
- Waves in Incompressible Fluids
- One-Dimensional Compressible (i.e., supersonic) Inviscid Flow
- Two-Dimensional Compressible Inviscid Flow

Bibliography

- *Theoretical Fluid Mechanics*, R. Fitzpatrick 2017. To be made available via Canvas. Main text for class.
- *An Introduction to Fluid Mechanics*, G.K. Batchelor (Cambridge, 2000). A classic textbook that is particularly good at explaining fundamental assumptions underlying fluid mechanics.
- *Statics, Including Hydrostatics and the Elements of the Theory of Elasticity*, H. Lamb (Cambridge, 3rd edition, 1928). Main source for hydrostatics.
- *Hydrodynamics*, H. Lamb, (Cambridge, 6th edition, 1993). Very comprehensive treatment of inviscid incompressible fluid flow.
- *Boundary Layer Theory*, H. Schlichting (McGraw-Hill, 7th edition, 1987). The standard text for boundary layer theory.
- *Theoretical Aerodynamics*, L.M. Milne-Thompson (Dover, 4th edition, revised and enlarged, 1958). The standard text for theoretical aerodynamics.
- *Waves in Fluids*, J. Lighthill (Cambridge, 1978). The standard text for waves in fluids.
- *Elements of Gasdynamics*, H.W. Liepmann, and A. Roshko (Wiley, 1957). The standard text for supersonic fluid flow.