Introduction to Turbulence (Web Course)

Faculty Coordinators

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Detailed Syllabus

Module 1: Introduction and Origin of Turbulence
Introduction: Properties of laminar flow, Properties of turbulent flow.
Boundary Layer: Boundary Layer, Growth rate of Boundary layer for Laminar and Turbulent Flows.
Characteristics of Turbulent Flow: The Origin of Turbulence, Nature of Turbulence, Swirling Structure, Mean Motion and Fluctuations, Consequences of Turbulence, Homogeneous-Isotropic Turbulence.

Module 2: Correlation Functions, Kolmogorov Hypothesis and Probability Density Function
Correlation Functions and Intensity: Correlation Functions, Ideas about eddy size, Intensity of Turbulence or Degree of Turbulence .
Kolmogorov Hypothesis and Energy Cascade: Kolmogorov Universal Law for the Fine Structure, Energy Cascade, Kolmogorov Length Scale, Kolmogorov's First Hypothesis, Kolmogorov's Second Hypothesis.
Probability Density Functions and Averaging: Introduction, Probability density function, Averaging used in the analysis of turbulent flows.

Module 3: Reynolds Averaged Navier-Stokes Equations and Classical Idealization of Turbulent Flows

Reynolds' Averaged Navier-Stokes Equations: Further on Laws of Averaging, Reynolds' Decomposition, Examples of Turbulent Fluctuations, Some Measurements on Fluctuating Components.
Measurements on Fluctuating Components: Shear Stress due to the Fluctuations, The boundary layer measurements of Klebanoff.
Turbulent Boundary Layer Equations: Turbulent Boundary Layer Equations for a two-dimensional flow.
Classical Idealisation of Turbulent Stresses: Introduction, The Boussinesq or eddy viscosity model, Eddy viscosity.

Module 4: Vorticity Dynamics
Vorticity Dynamics: Introduction, Vorticity and the equations of motion, Reynolds stress and vorticity.
Vortex Stretching: Vortex Stretching.
Further on Vortex Stretching: The Vorticity Equation, Vorticity in Turbulent Flows.

Module 5: Dynamics of Turbulent Kinetic Energy and Important Scaling Relations
Dynamics of Turbulence: Kinetic Energy : Kinetic Energy of the Mean Flow.
Kinetic Energy of Fluctuations: Kinetic Energy of Fluctuations.
Some Scaling Relations: Some Scaling Relations.

Module 6: Wall Bounded Flows and Free Shear Flows
The Law of the Wall for Wall Bounded Flows: The Law of the Wall for Wall Bounded Flows, The Universal Velocity Profile.
Turbulent Jet: Free Shear Flows, Turbulent Jets, Uniform Eddy Viscosity model .

Module 7: Spectral Dynamics
Spectral Dynamics: Correlation Functions and Spectra.
The Energy Cascade: The Energy Cascade

Module 8: Large - Eddy Simulation of Turbulent Flows
RANS Equations and Eddy Viscosity : Introduction Reynolds Averaged Navier-Stokes (RANS) Equations, Eddy Viscosity Models, Zero-Equation Models.

One-Equation Model: One-Equation Model, Two-Equation Model.
Two Equation Models: k - ω Model, SST (Shear Stress Transport) Turbulence Model.
Two Equation Models (Continued): SST Model, Discussion on Applicability
Low Reynolds number k - ε model: Special Features of Near Wall Flow, Near Wall Treatment in Transport Equation based Models, Wall Function Approach, Low Reynolds number version of k - ε model: Asymptotic Consistency, Damping Functions.
RNG k - ε Model and Kato-Launder Model: RNG k - ε Model and Kato-Launder Model.
Mathematical Modeling of Turbulent Flows: The Realizable k - ε Model, Reynolds Stress Models (RSM), Large Eddy Simulation (LES).
Mathematical Modeling of Turbulent Flows: The Filtered Navier-Stokes Equations, Subgrid-Scale Closure, Standard Subgrid-Scale Model.
Dynamic Model of LES : Dynamic Model of LES.
Other Developments in SGS Closure: Renormalization Group Model (Yakhot et al., 1989), Structure Function Model (Metais and Lesieur, 1991), Some LES Results.
Direct Numerical Simulation: Direct Numerical Simulation.

TEXT BOOKS

The author is inspired by the following text books:

1. H. Tennekes and J.L. Lumley, 1987, A First Course in Turbulence, The MIT Press, Cambridge, Massachusetts, and London, England.

2. P.K. Kundu and I.M. Cohen, 2002, Fluid Mechanics, Academic Press (An Imprint of Elsevier Science, USA.

3. S.B. Pope, Turbulent Flows, 2000, Cambridge University Press, UK.

4. G. Biswas and V. Eswaran, 2002, Turbulent Flows: Fundamentals, Experiments and Modeling, Narosa Publishing House, New Delhi, India.