SYLLABUS

INTRODUCTION TO TURBULENT FLOWS AND THEIR PREDICTION

1. Introduction
2. Experimental techniques
3. Equations governing turbulent flows
4. Benchmark data and features of basic turbulent flows
5. Turbulence modelling
6. Numerical scheme for prediction of thin shear flows and miscellaneous topics

Appendix A – Historical background
Appendix B – Cartesian tensors
Appendix C – Review of basic concepts and equations of fluid dynamics
Appendix D – Elements of laminar boundary layers and transition
Appendix E – Equation for dissipation
Appendix F - Term paper titles

1. Introduction.

Definition of turbulence; Features of turbulence – irregularity, diffusivity, high Reynolds number, rotational, dissipative, continuum phenomenon; Characterisation of turbulent flows – statistical averages, moments, probability density function, correlation, spectrum, scales, intermittency, quadrant analysis.

2. Experimental techniques

Need for special techniques; Hot-wire anemometry ; LASER Doppler Velocimetry ; Particle Image Velocimetry.

3. Equations governing turbulent flow

Reynolds averaged Navier – Stokes Equations; Equations for Reynolds stresses, mean and turbulent kinetic energy ; Energy transfer in turbulent flows ; Closure problem ; Boundary layer equations for turbulent flows ; Momentum integral equation for turbulent boundary layer ; Reynolds averaged and mass weighted equations for compressible flows.

4. **Bench mark data and features of basic turbulent flows.**

   Validation of CFD codes and need for benchmark data; Characteristics of good Data – reliability and consistency; Test cases for turbulent flows – homogeneous flows, thin shear flows, sources of benchmark data.

5. **Turbulence modelling.**

   Outline of approaches to prediction of turbulent flows ; Desirable futures of a model of turbulence; Zero -, one -, half - , and two- equation models of turbulence; Reynolds stress model ; Algebraic stress model ; Three-equation model; Limitations of RANS approach.

6. **Numerical scheme for predicting thin shear flows and miscellaneous topics**

   Thin shear flow equations; Elements of finite volume scheme; Examples of computations. References for computation of separated flows using models of turbulence, LES, DNS; use of commercial course.

Appendix A : Historical background
Appendix B : Cartesian tensors
Appendix C : Review of basic concepts and equations of fluid dynamics
Appendix D : Elements of laminar boundary layers and transition
Appendix E : Equation for dissipation.
Appendix F: Term paper topics

1. Course Pre-requisites	(a) Basic fluid dynamics (b) Boundary layers

2. Text/References

1. Pope S.B. "Turbulence" Cambridge University Press, Cambridge, U.K., 2000.

2. Biswas, G. and Eswaran, V. "Turbulent flows" Narosa Publishing House New Delhi, India, 2002.

3. Davidson P.A, "Turbulence" Oxford University Press, Oxford, U.K, 2004.

4. Wilcox, D.C. "Turbulence modeling for CFD", DCW Industries, La Canada, CA, 3rd edition 2006.

5. Durbin, P .A. and Paterson. Reif, B.A. "Statistical theory and modeling for turbulent flows"2nd edition, John Wiley, Chichester, U.K, 2011.

6. Hanjalic, K. and Launder, B. " Modelling of turbulence in engineering and environment – Second moment route to closure" Cambridge University Press, Cambridge, U.K., 2013

3. Suggested /Additional Reading

1. Tennekes,H. and Lumley, J.L." A first course on turbulence"MIT Press, Cambridge Mass., 1972.

2. Durst, F. Melling, A. and Whitelaw, J.H. "Principle and practice of Laser Doppler anemometer" Second Edition Academic Press London 1981.

3.Brunn H.H "Hot-Wire Anemometry" Oxford university press, Oxford, 1995.

4.Tannehill, S.C. Anderson, D.A. and Pletcher, R.H. "Computational fluid mechanics and heat transfer", Taylor & Francis, Washington, D.C, 1997.

5. Raffel, M. Willert, C.E and Kompenhans, J "Particle image velocitmetry" Springer Verlag Berlin Heidelburg, 1998.

6. Cebeci, T. and Cousteix, J. "Modeling and computation of boundary layer flows" Horizons Publishing, Long Beach, CA, 1999.

7. Fergizer .J.H and Peric .M. "Computational method for fluid dynamics" Springer, Berlin, Heidelberg 1999.

8. Schlichting, H. and Gersten , K. "Boundary layer theory" 8th Edition, Spinger-Verlag, 2000

9. Cebeci. T, 'Modeling and computation of turbulent flows", Elsevier, Amsterdam, 2003