6 Introduction to Turbulent Boundary Layers

6.1 The nature of flow in turbulent boundary layers. Inner and outer regions, eddy diffusivity distributions, intermittency, etc.

6.2 Integral form of the mean flow boundary layer equations.

6.3 Reasons for why the turbulent boundary layer velocity profile must be defined in terms of *at least two* parameters [e.g. $\delta(x)$ and u] in turbulent flow, vs. only one [e.g. $\delta(x)$] in laminar boundary layer.

6.4 Cole's "universal" mean−velocity profile for the logarithmic and outer regions in a turbulent boundary layer, expressed in terms of a wake function $W(y/\delta)$ and profile parameter $\Pi(\beta)$.

6.5 Use of Cole's velocity profile in the integral boundary layer equation, for arbitrary pressure gradient.

6.6 Examples: solutions for smooth and rough flat plates; admissible roughness.

6.7 On the physical nature of the flow in boundary layers: turbulence bursts, bursting frequency, etc., and its relationship to drag. Drag reduction by optimized microgrooves (riblets).

Readings:

Pope, p. 298 ff.
White, pp 409−421, 429−443.
Schlichting, Chapter 21.
Bradshaw, Chapter 2.
Cebeci & Smith. *Analysis of Turbulent Boundary Layers.* Academic, 1974.

•For Section 6.7, see for example: Bushnell & McGinley, "Turbulence control in wall flows". *Ann. Rev. Fluid Mec h.,* Vol. 2 (1989): p 1 for an overview.
•See Hinze, pp 681−84 for the physical picture (but *not* for the scaling laws for the bursting frequency, for which better expressions are found in Blackwelder & Haritonidis, *J. Fluid Mech.* 132 (1983): 87−103.
•For drag reduction by riblets, see for example: Walsh & Lindemann, AIAA−84−0347; Gallagher & Thomas, AIAA−84−2185; Bechert et al, AIAA−85−0546.