

Turbulent Flow and Transport

5 Bounded Flows I: General Near-Wall Scaling Laws; Flows in Pipes, Channels, etc.

- 5.1 Division of a wall-bounded turbulent shear flow into an inner (or constant-shear) layer near the wall, and an "outer layer." Prandtl's "universal law of the wall"— a universal scaling law for the mean velocity and the turbulence properties in the inner layer. The viscous and inertial (or logarithmic) sublayers of the inner layer, and the mean velocity profile in each of these layers, based on dimensional and mixing-length arguments. Comparison with experimental data. The velocity-defect "law" for the mean velocity in the outer layer.
- 5.2 Turbulent eddy diffusivity in the inner layer. Universal expressions for $y_+ \rightarrow 0$ (based on Taylor expansion about $y=0$) and $y_+ \rightarrow \infty$ (based on the logarithmic profile). Some postulated expressions for the entire inner layer: Reichardt's, Deissler's, Van Driest's, etc.
- 5.3 Turbulent Couette flow between smooth plates: a model for the mean velocity distribution and the relation between the velocity and the applied shear stress (i.e. the friction factor vs Reynolds number relation) based on a postulated turbulent kinematic viscosity distribution.
- 5.4 Fully developed turbulent flow in smooth-walled pipes. Various derivations for the relation between friction factor and Reynolds number, e.g. based on a turbulent diffusivity distribution. Analogous relations for channel flows.
- 5.5 Turbulent flow over rough walls. The mean velocity distribution in the inner (constant-shear) layer. Empirical correlations for the roughness effect. Flow in rough-walled pipes and channels.
- 5.6 Temperature (or concentration) distribution in the inner layer. Reynolds' analogy between thermal and mean velocity profiles for $Pr=1$. General analytic solution for heat transfer coefficient for very large Prandtl numbers, expressed in terms of local wall shear stress and fluid properties. Convective heat (or mass) transfer in fully developed internal flow.

Readings:

Pope. Secs 7.1–7.2, 10.1–10.2
White. 2nd ed. pp. 411–416, 421–429, 436–440
Schlichting. Chapters 19 & 20
Monin & Yaglom I. Chapter 3, Secs. 5.2 – 5.5
Tennekes & Lumley. pp 147–165, 171–176