

Turbulent Flows
 Stephen B. Pope
Cambridge University Press (2000)

Solution to Exercise 10.3

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Date: 3/27/03

- a) Consider the log-law region of a wall-bounded turbulent flow. The turbulent viscosity hypothesis say

$$-\langle uv \rangle = \nu_T \frac{\partial \langle U \rangle}{\partial y}. \quad (1)$$

With $\nu_T = ck^{1/2} \ell_m$, we get

$$\langle uv \rangle = -ck^{1/2} \ell_m \frac{\partial \langle U \rangle}{\partial y}. \quad (2)$$

According to the log-law

$$u^+ = \frac{1}{\kappa} \ln y^+ + B \quad (3)$$

where $y^+ = \frac{y}{\delta_\nu} = \frac{u_* y}{\nu}$, $u_* = \sqrt{\tau_w / \rho}$, $\delta_\nu = \frac{\nu}{u_*}$ and $u^+ = \frac{\langle U \rangle}{u_*}$, we get

$$\begin{aligned} \frac{\partial \langle U \rangle}{\partial y} &= \frac{u_*^2}{\nu} \frac{du^+}{dy^+} = \frac{u_*^2}{\nu \kappa y^+} \\ &= \frac{u_*}{\kappa y}. \end{aligned} \quad (4)$$

Substituting Eq. 4 into Eq. 2, we get

$$\langle uv \rangle = -ck^{1/2} \ell_m u_* / (\kappa y). \quad (5)$$

In the log-law region of a wall-bounded turbulent flow, $\langle uv \rangle \approx -\tau_w / \rho$, so

$$u_* = |\langle uv \rangle|^{1/2}. \quad (6)$$

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