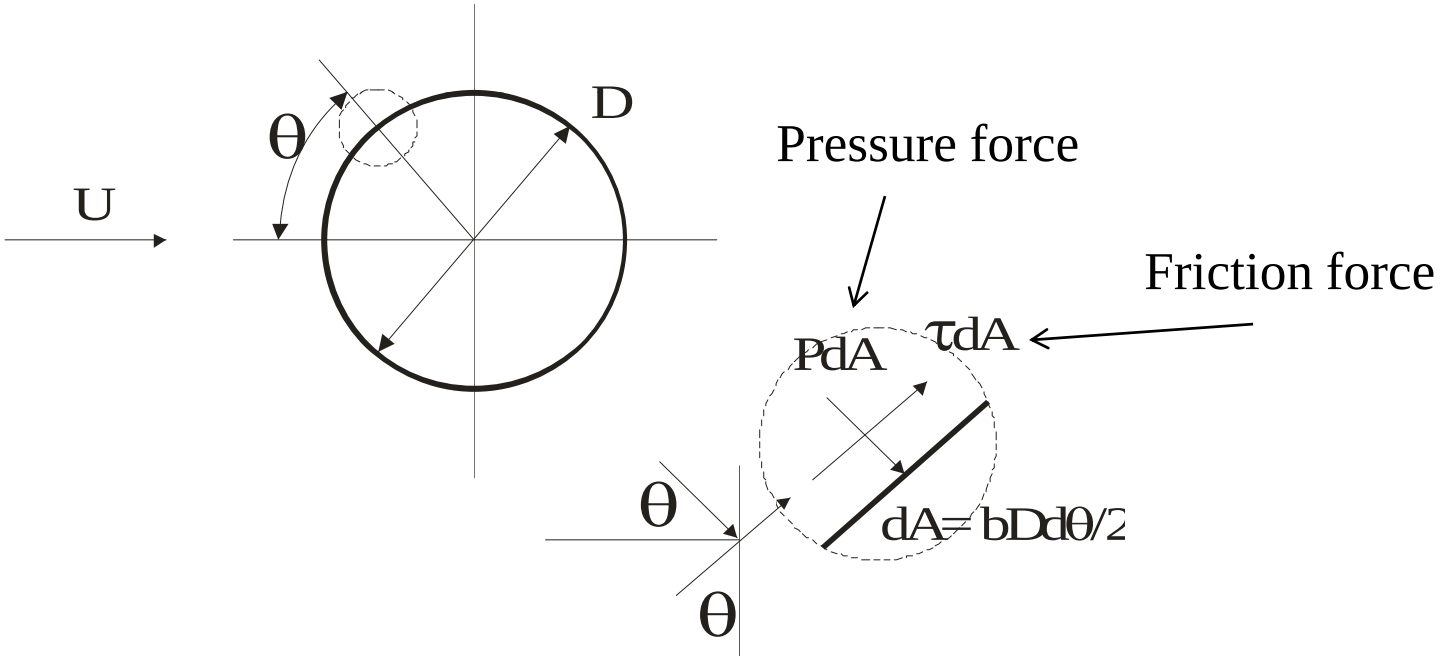
External Viscous Flow

Consider External Flow around a cylinder and the external forces acting on the surface of the cylinder in crossflow.



Total Drag

Total force in horizontal direction (fluid direction) due to fluid pressure forces and shear forces.

$$D_T = D_p + D_f$$

$$D_T = b\frac{D}{2}\left[\int_A P\cos\theta\, d\theta + \int_A \tau_w \sin\theta\, d\theta\right]$$

Drag Coefficient

Without detailed information, the alternative is to define a dimensionless drag coefficient.

$$C_D = \frac{D_T}{\frac{1}{2}\rho U^2 A_c}$$

where A_c is a characteristic area (usually projected area).

Drag Coefficient

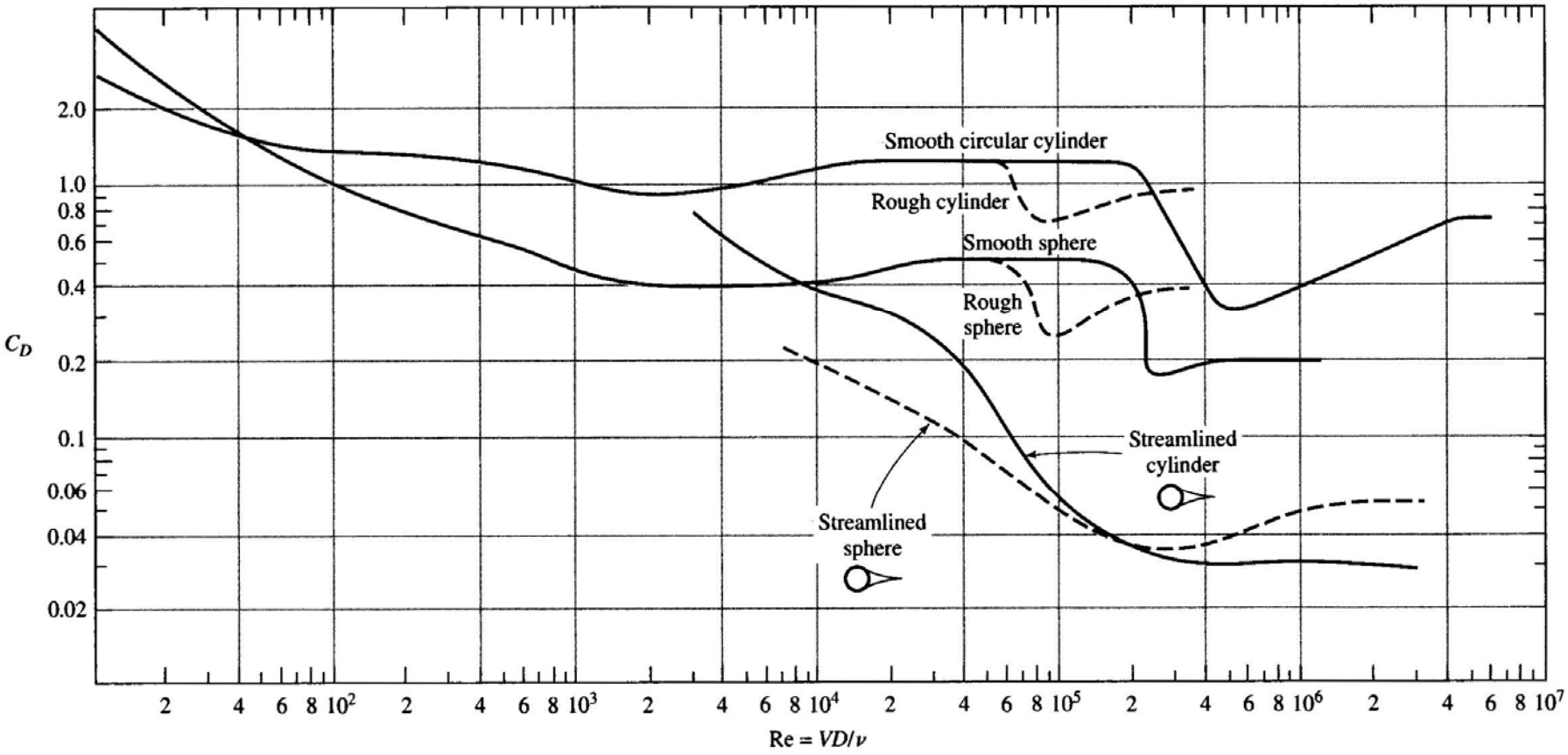


FIGURE 8.9 Drag coefficients for flow around a long cylinder and a sphere. (See E. Achenbach, *J. Fluid Mech.*, Vol. 46, 1971, and Vol. 54, 1972.)

Boundary Layers with Pressure Gradient

Consider the extreme case of flow around a vertical flat plate (blunt object).

- Form Drag or Pressure Drag

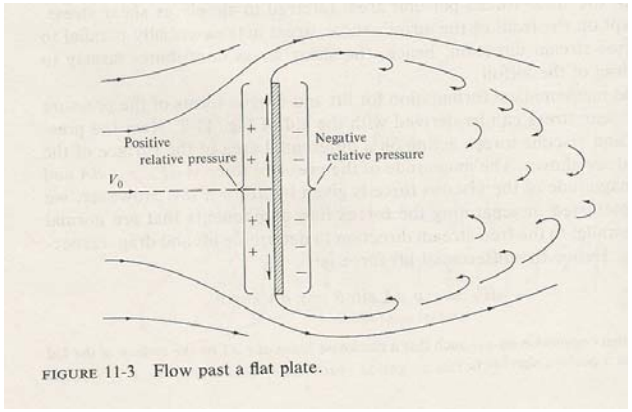
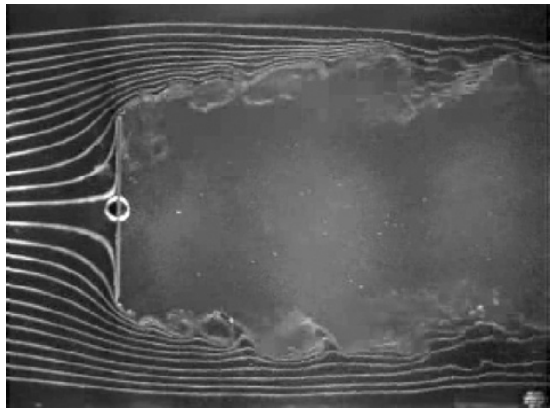
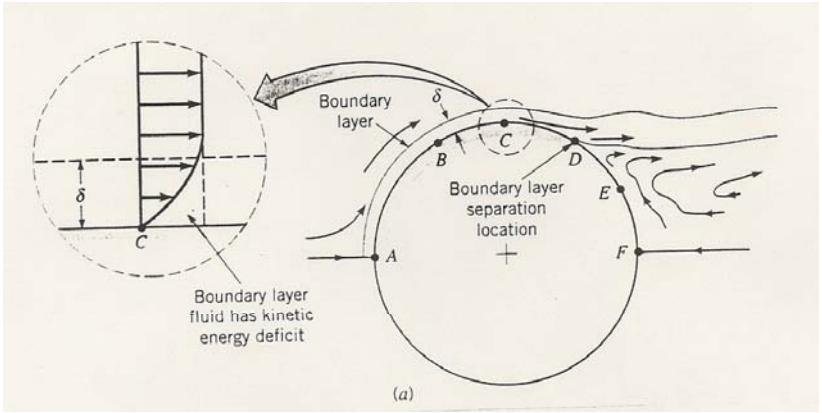


FIGURE 11-3 Flow past a flat plate.

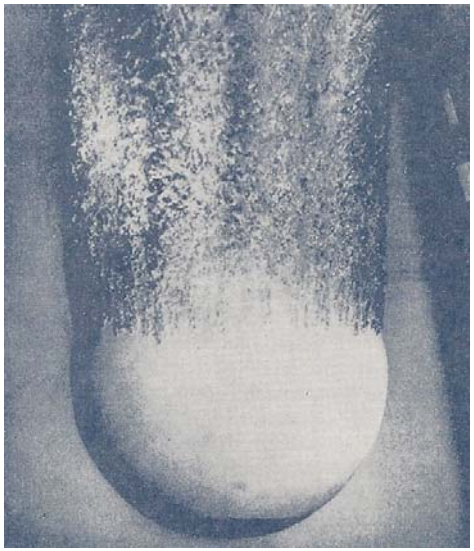


Boundary Layers with Pressure Gradient

Flow around a cylinder or sphere.



Laminar



Turbulent

Example

Problem

Determine the drag force for a 3 m long, 30 cm diameter cylinder. The air velocity is 35 m/s at 1 atm and 20 C.

Solution

$$F_D = C_D \frac{1}{2} \rho V^2 (DL)$$

The air properties are:

$$\mu = 1.79 \text{ x } 10^{-5} \text{ N - s/m}^2 \qquad \rho = 1.21 \text{ kg/m}^3$$

$$\text{Re}_D = \frac{\rho V D}{\mu} = 7.1 \times 10^5$$

Drag Coefficient

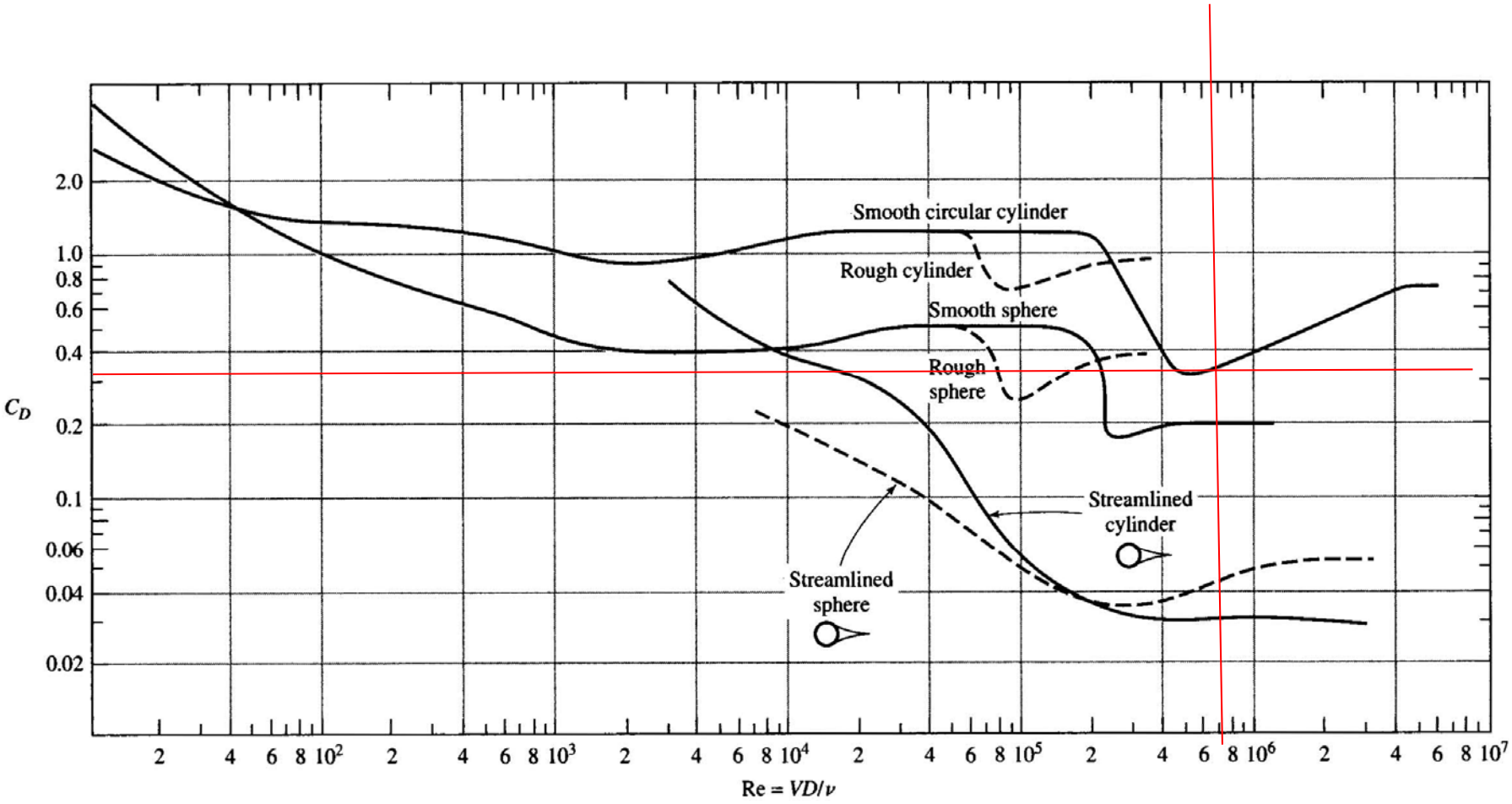


FIGURE 8.9 Drag coefficients for flow around a long cylinder and a sphere. (See E. Achenbach, *J. Fluid Mech.*, Vol. 46, 1971, and Vol. 54, 1972.)

Example

The drag coefficient from figure.

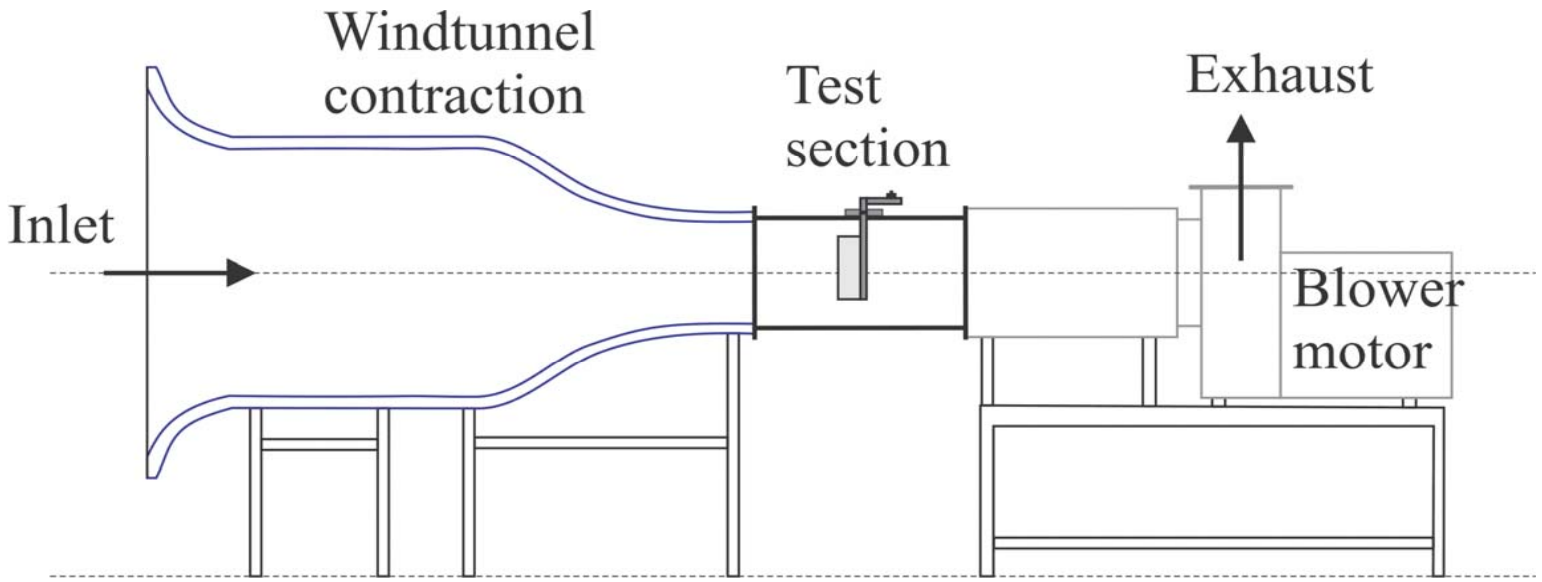
$$C_D \approx 0.3$$

$$F_D = C_D \frac{1}{2} \rho V^2 (DL)$$

$$= \underline{\underline{200 \text{ N}}}$$

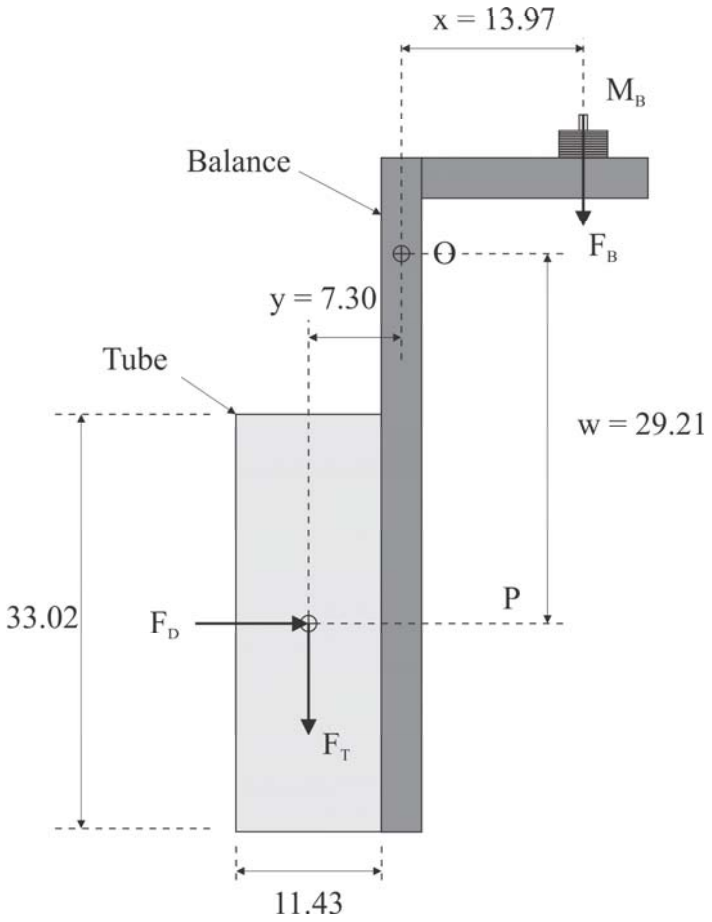
External Flow Experiment

The windtunnel is used for this experiment. A cylinder is attached to a mechanical balance in the test section.



External Flow Experiment

The force diagram for the cylinder – mechanical balance.



- Set blower speed.
- Add counterweights to align cylinder vertically.
- Record counterweights.
- Determine drag force and coefficient.

$$+cw\sum M_O = 0$$

$$xF_B - yF_T - wF_D = 0$$

$$C_D = \frac{2F_D}{\rho V^2 (DL)}$$