Problem 7.7

Given: At low speeds, drag is independent of fluid density.

$$F = F(\mu, V, D)$$

Find: Appropriate dimensionless parameters.

<u>Solution</u>: Apply Buckingham Π procedure.

① $F \quad \mu \quad V \quad D$ $\qquad$ $n = 4$ parameters

② Select primary dimensions M, L, t.

③ $F \quad \mu \quad V \quad D$

$\frac{ML}{t^2} \quad \frac{M}{Lt} \quad \frac{L}{t} \quad L$ $\qquad$ $r = 3$ primary dimensions

④ μ, V, D $\quad m = r = 3$ repeating parameters

⑤ Then $n - m = 1$ dimensionless group will result. Setting up a dimensional equation,

$$\Pi_1 = \mu^a V^b D^c F$$

$$= \left(\frac{M}{Lt}\right)^a \left(\frac{L}{t}\right)^b (L)^c \frac{ML}{t^2} = M^0 L^0 t^0$$

Summing exponents,

$$\begin{array}{ll|l} M: & a + 1 = 0 & a = -1 \\ L: & -a + b + c + 1 = 0 & c = -1 \\ t: & -a - b - 2 = 0 & b = -1 \end{array} \qquad \therefore \Pi_1 = \frac{F}{\mu V D}$$

Π_1

⑥ Check, using F, L, t primary dimensions.

$$\Pi_1 = F \frac{L^2}{Ft} \frac{t}{L} \frac{1}{L} = [1] \quad \checkmark$$

Since the procedure produces only one dimensionless group, it must be a constant. Thus

$$\Pi_1 = \frac{F}{\mu V D} \quad \text{or} \quad F \propto \mu V D$$