7.55 The drag on a small, completely submerged solid body having a characteristic length of 2.5 mm and moving with a velocity of 10 m/s through water is to be determined with the aid of a model. The length scale is to be 50, which indicates that the model is to be larger than the prototype. Investigate the possibility of using either an unpressurized wind tunnel or a water tunnel for this study. Determine the required velocity in both the wind and water tunnels, and the relationship between the model drag and the prototype drag for both systems. Would either type of test facility be suitable for this study?

As demonstrated in Eq. 7.14, for flow around immersed bodies, Reynolds number similarity is required so that

\[
\frac{V_m}{V} = \frac{V_m}{V}
\]

or

\[
V_m = \frac{V_m L_m}{V L_m}
\]

If model tests are run in unpressurized wind tunnel, then

\[
V_m (\text{standard air}) = 1.46 \times 10^{-5} \text{ m}^2/\text{s}, \quad \text{and} \quad V (\text{water}) = 1.12 \times 10^{-6} \text{ m}^2/\text{s},
\]

so that

\[
V_m = \left(1.46 \times 10^{-5} \text{ m}^2/\text{s}\right) \left(\frac{1}{50}\right) \left(10 \text{ m/s}\right) = 2.61 \text{ m/s} \quad \text{(for wind tunnel)}
\]

If model tests are run in water tunnel with \( V_m = V \), then

\[
V_m = \left(1\right) \left(\frac{1}{50}\right) \left(10 \text{ m/s}\right) = 0.200 \text{ m/s} \quad \text{(for water tunnel)}
\]

Since \( V_m \) is reasonable in both cases, either the wind tunnel or the water tunnel could be used. With geometric and dynamic similarity, it follows that

\[
\frac{D}{\rho V^2 L^2} = \frac{D_m}{\rho_m V_m^2 L_m^2}
\]

or

\[
\frac{D}{\rho_m V_m^2 L_m^2} = \frac{D_m}{\rho V^2 L^2}
\]

Thus, for wind tunnel tests

\[
\frac{D}{\rho_m} = \frac{(999 \text{ kg/m}^3)}{(1.46 \times 10^{-5} \text{ m}^2/\text{s})^2} \left(\frac{1}{50}\right)^2 = 213 \quad \text{(for wind tunnel)}
\]

and for water tunnel tests

\[
\frac{D}{\rho_m} = \frac{1.10}{(0.300 \text{ kg/m}^3)^2} \left(\frac{1}{50}\right)^2 = 0.444 \quad \text{(for water tunnel)}
\]