A 38.1-mm-diameter, 0.0245-N table tennis ball is released from the bottom of a swimming pool. With what velocity does it rise to the surface? Assume it has reached its terminal velocity.

For steady rise, \( \sum F_z = 0 \)

or

\[
F_B = W + D, \quad \text{where} \quad D = \text{drag} = C_D \frac{1}{2} \rho U^2 \frac{D^2}{2}
\]

\[
W = \text{weight} = 0.0245 \text{N}
\]

\[
F_B = \text{buoyant force} = \rho V = \rho \frac{4}{3} \pi \left( \frac{D}{2} \right)^3
\]

Thus,

\[
\frac{4}{3} \pi \left( \frac{D}{2} \right)^3 = W + C_D \frac{1}{2} \rho U^2 \frac{D^2}{4}
\]

or

\[
(9.80 \times 10^4 \text{m}^{-3}) \frac{4}{3} \pi \left( \frac{0.0381}{2} \right)^3 = 0.0245 \text{N} + \frac{1}{2} C_D (999 \text{kg/m}^3) U^2 \frac{1}{4} (0.0381 \text{m})^3
\]

or

\[
C_D U^2 = 0.455, \quad \text{where} \quad U \sim \frac{m}{s}
\]

Also, \( Re = \frac{U D}{\nu} \)

or

\[
Re = \frac{U (0.0381 \text{m})}{1.12 \times 10^{-6} \text{m}^2/\text{s}} = 3.40 \times 10^4 U, \quad \text{where} \quad U \sim \frac{m}{s}
\]

Finally, from Fig. 9.21: \( C_D \)

\[
\begin{array}{c}
\text{Re} \\
3.40 \times 10^4 U
\end{array}
\]

Trial and error solution: Assume \( C_D \); obtain \( U \) from Eq. (1), \( Re \) from Eq. (2); check \( C_D \) from Eq. (3), the graph.

Assume \( C_D = 0.5 \) \( \rightarrow \) \( U = 0.954 \frac{m}{s} \) \( \rightarrow \) \( Re = 3.24 \times 10^4 \) \( \rightarrow \) \( C_D = 0.4 \pm 0.5 \)

Assume \( C_D = 0.4 \) \( \rightarrow \) \( U = 1.06 \frac{m}{s} \) \( \rightarrow \) \( Re = 3.62 \times 10^4 \) \( \rightarrow \) \( C_D = 0.4 \) (checks)

Thus, \( U = 1.06 \frac{m}{s} \)

Note: Because of the graph (Fig. 9.21) the answers are not accurate to three significant figures.