**Problem 9.116**

A thin-walled plastic sphere 10 mm in diameter with mass of 0.05 g, immersed in a glycerin bath at a depth of 1 m, is released and begins to rise to the surface. Calculate the time required for the sphere to reach the surface.

**Given:**
Thin walled plastic sphere with \( D = 10 \text{ mm} \) and \( m = 0.05 \text{ g} \), immersed in glycerin bath at depth, \( h = 1 \text{ m} \), is released and rises to the surface.

\[
m_B := 0.05 \text{ gm} \quad D := 10 \cdot \text{mm} \quad h := 1 \cdot \text{m}
\]

**Find:**
Time needed to reach the surface

**Solution:**
Apply Newton's second law of motion and definition of \( C_D \)

Computing equation:

\[
\sum F_y = ma_y \quad C_D = \frac{24}{Re} \text{ for } Re < 1
\]

Assume : \( V = V_t \), so \( a_y = 0 \); terminal speed reach quickly

Summing forces, \( F_B - mg - F_D = 0 \)

But \( F_B = \rho \text{Vol} m g = \rho \left( \frac{\pi D^3}{6} \right) g \)

and

\[
F_D = C_D \left( \frac{\rho V_t^2 A}{2} \right) = \left( \frac{24}{V_D} \right) \left( \frac{\rho V_t^2}{2} \right) \left( \frac{\pi D^2}{4} \right) = 3\pi \mu V_t D
\]

Substituting

\[
\frac{\rho \pi D^3 g}{6} - mg - 3\pi \mu V_t D = 0
\]

So

\[
V_t := \left( \frac{g}{3\pi \mu \rho \text{gl} D} \right) \left[ \rho \text{gl} \left( \frac{D^3}{6} \right) - m_B \right]
\]

\[
V_t = 0.045 \frac{m}{s}
\]
Then
\[ t := \frac{h}{V_t} \]
\[ t = 22.091 \text{ sec} \]  \hspace{1cm} \text{Time needed to reach the surface, } t = 20.091 \text{ sec}

Check
\[ \text{Re} := \frac{\rho_g V_t D}{\mu_g} \]
\[ \text{Re} = 0.407 \]

Since, \( \text{Re} < 1 \), stokes flow is a reasonable assumption.