Terminal velocity (v_t):

Terminal velocity is defined as the maximum (and steady) velocity attained by an object falling through a fluid.

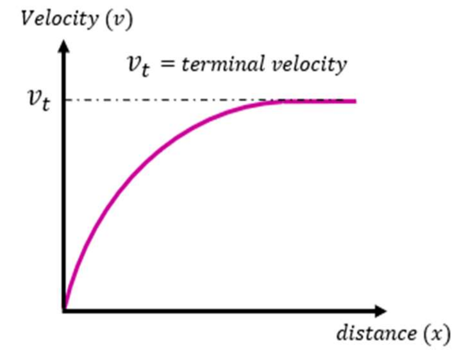

Figure: Variation of velocity of ball falling down a viscous fluid.

Expression for coefficient of viscosity from Stoke's method:

If a sphere of radius r and density ρ falls under gravity in a liquid of density σ at a constant velocity v_t, then

$$Total\ upward\ force = Total\ downward\ force$$

or, $$F_v + U = mg$$

or, $$6\pi\eta r v_t + \frac{4}{3}\pi r^3 \sigma g = \frac{4}{3}\pi r^3 \rho g$$

or, $$6\pi\eta r v_t = \frac{4}{3}\pi r^3 (\rho - \sigma) g$$

or, $$v_t = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{\eta}$$

Expression for terminal velocity (if η is known)

or, $$\eta = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{v_t}$$

Expression for coefficient of viscosity.

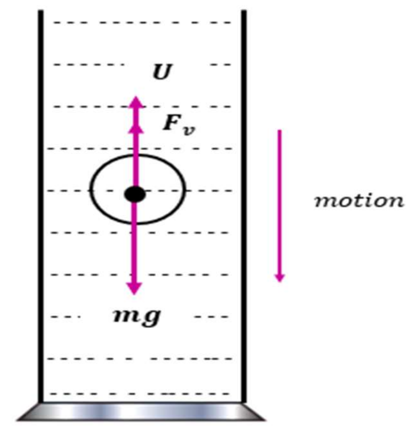

Figure: Motion of a solid ball in a viscous fluid

Working formula:

- To find terminal velocity ($\boldsymbol{v_t}$):

  If, $d = distance\ travelled\ by\ the\ sphere\ inside\ the\ fluid\ at\ steady\ state$

  $t = time\ taken\ to\ travel\ then\ distance$

  Then, terminal velocity,

$$\boldsymbol{v_t = \frac{d}{t}}$$

- To find the coefficient of viscosity of fluid ($\boldsymbol{\eta}$)
  - ✓ The coefficient of viscosity is:

$$\boldsymbol{\eta = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{v_t}}$$

Unit of $\boldsymbol{\eta}$:
SI: Nsm^{-2} or Pa s or *decapoise*
CGS: Dyne s cm^{-2} or poise

$$\boldsymbol{1\ poise = \frac{1}{10}\ decapoise}$$

PROCEDURE:

1. Take a long transparent clean jar.
2. Fill the jar with a given experimental liquid (whose coefficient of viscosity has to be determined).
3. Mark two points A and B on the jar, as shown. Mark the point A at certain diatance below the surface of liquid so that when the ball reaches the point it would have acquired terminal velocity. Note the distance (D) between the points A and B.
4. Determine the diameter (and hence radius) of a ball bearing and drop it gently into the liquid. When the ball crosses the point A, start the stop watch and stop the watch when the ball crosses the point B. Note down the corresponding time.
5. Repeat the step 4 for other four different sized steel balls.