Measurement of fluid viscosity

The aim of Experiment:

To determine the coefficient of viscosity for glycerin

Theory:

The viscosity of liquid is a resistance to flow of a liquid. All liquids appear resistance to flow change from liquid to another, the water faster flow than glycerin, subsequently the viscosity of water less than glycerin at same temperature.

When a spherical ball of radius r and density (ρ) falls freely through a viscous liquid of density (σ) and coefficient of viscosity (η), it moves in it with certain velocity (v), it experiences an opposing force, drag force, (viscous force F_d). According to Stoke's law this viscous force is given by:

$$F_d = 6\pi r\eta v \qquad \dots.(1)$$

Simultaneously it experiences an upthrust (or buoyant force) F_b and weight force F_w. F_w tries to increase the velocity of ball whereas F_d decreases the velocity. After some time the ball will move with a steady velocity, called the terminal velocity. Under the steady condition.

$$F_w = F_b + F_d \qquad \dots.(2)$$

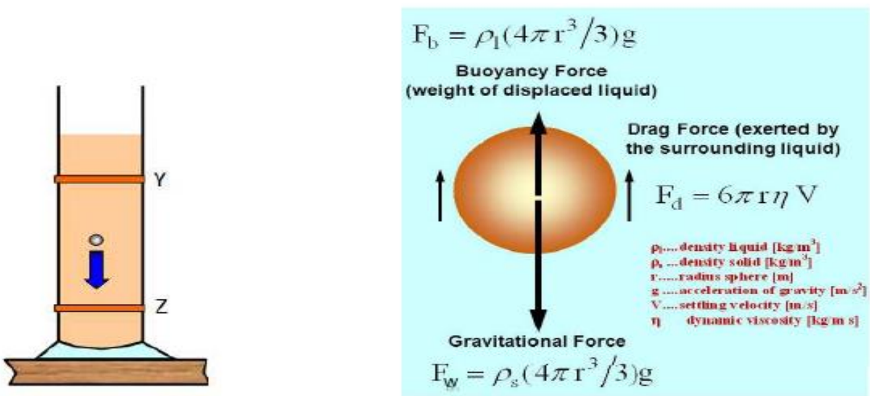


Fig. 1 The glass cylinder with the liquid

Let the radius of the ball = r, then the volume of the ball is $V = \frac{4}{3}\pi r^3$ and the density of the ball is $\rho = \frac{m}{V}$, where m is the mass of the ball. So, the weight of the ball is

$$F_w = mg = \rho V g = \rho\left(\frac{4}{3}\pi r^3\right) g \quad .....(3)$$

Let the density of liquid is σ. Using Archimedes principle buoyancy of liquid on the ball is given by,

$$F_b = \sigma\,(\frac{4}{3}\pi r^3\,)g \quad ......(4)$$

Using (1), (2), (3) and (4) we can show that:

$$\eta = \frac{2}{9}\frac{r^2}{v}(\rho - \sigma)g \quad ....(5)$$

The factors effect on the viscosity:

1. Effect of Temperature: the temperature of the liquid fluid increases its viscosity decreases. In gases its opposite, the viscosity of the gases fluids increases as the temperature of the gas increases.
2. Molecular weight: the molecular weight of the liquid increases its viscosity increases
3. Pressure: when increase the pressure on liquids, the viscosity increase because increase the attraction force between the molecules of liquid.

Tools used:

Stainless steel balls, Glass tube or Beaker, Stop watch, Glycerin, and two rubber bands.

Method of working:

1. Write the density of glycerin $\sigma = 1.23\ gm/cm^3$, and density of the ball's material, $\rho = 7.8\ gm/cm^3$.
2. Select the same sized balls that dropped into a measuring beaker containing glycerin. Then measure ball's diameter using a Vernier calipers.
3. Fix a mark, A (as shown in figure 1) on a baker below the surface of glycerin such that the ball achieves its terminal velocity while passing this mark . Fix another mark near the bottom of the baker (mark B in Figure 1).

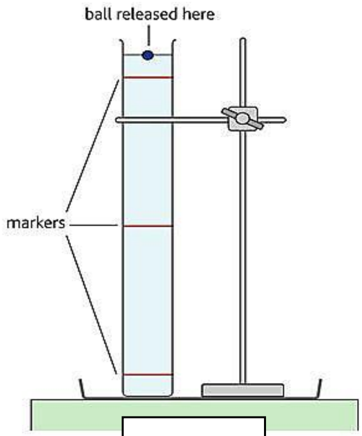
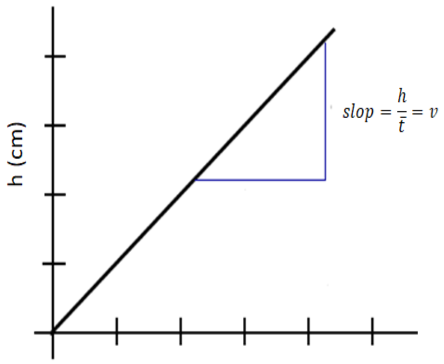


Figure 2

4. Measure the distance (h) between the two rubber bands (marks) and write it in the table.
5. Drop the ball at the middle of the top surface of the liquid. Then recorded the time (t) taken to travel a ball between two marks on the beaker (as shown in Figure 2) by a stop watch. Take t_1 and t_2, then measure the average readings $\bar{t}$ to reduce or eliminate any error present.
6. Repeat above steps with different values of dropping distance (h).
7. Then tabulate all the data as given below.

h (cm)	t_1(sec)	t_2 (sec)	$\bar{t}$ (sec)

8. Plot graph with the distance (h) on the y-axis and the average time $(\bar{t})$ on the x-axis. The gradient of line of best fit will be the velocity of ball (in cm per sec).



9. Finally use equation (5) to measure the coefficient of glycerin's viscosity, by:

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

Questions of the experiment:

Q1/ what is the terminal velocity?

Q2/ A ball of diameter 3.6 mm is made of steel. It is released into glycerin and falls. Calculate:

(a) the terminal velocity, if the density of this grade of steel is 8050 $Kg.m/m^3$.

(b) Buoyancy force.

(c) Weight of the ball.

(d) the Resultant Force.