**Experiment No.11**

**The Viscosity.**

## Objective:

1- To show where a small sphere falls with constant terminal velocity inside a viscous fluid

2- To determine the viscosity coefficient $\eta$ of a fluid

## Theory:

The resistance to the fluid flow due to the internal friction between adjacent fluid layers is called **viscosity**.

When a solid sphere is moving in a liquid, a viscous drag force **$F_D$** will be exerted on the sphere. According to Stokes' law, the drag force is proportional to the viscosity of the fluid, the **radius r =d/2** of the sphere, and the velocity (or speed) of the

$$F_D = 6\pi\eta rv = 3\pi\eta dv$$

Where, $\eta$ is the coefficient of viscosity fluid. A steel ball is dropped into a fluid sample so that the gravitational force on the ball, **$F_G$ = mg**, is larger than the buoyant force **$F_B$**. The net driving force *F* on the ball is:

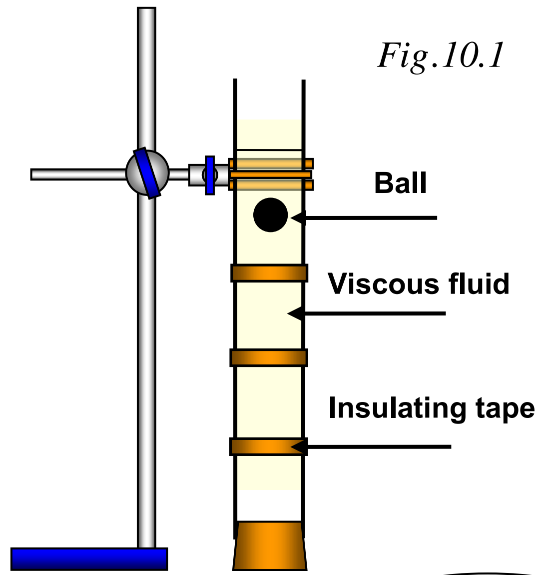

*Fig.10.1*

$$mg - F_B = \frac{1}{6}\pi d^3(\rho - \rho_0)$$

If a sphere of diameter **d** and density **ρ** is allowed to fall from rest through a liquid of density **$\rho_o$**, it will accelerate by the gravitational force **$F_G$** opposed by viscous force **$F_D$**, and the buoyant force, or the upthrust force of the fluid **$F_B$**, until it reaches **<u>a constant terminal velocity $v_t$,</u>** at this point **$F_G$** is balanced by the **$F_D$** and **$F_B$**:

$$F_B + F_D = F_G$$

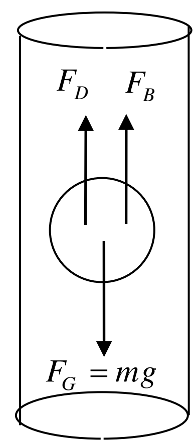

*Fig.10.2*

Gravitational force: $F_G = mg = \frac{1}{6}\pi d^3\rho g$, $\rho$ the density of the ball

Buoyant (upthrust) force: $F_B = \frac{1}{6}\pi d^3\rho_0$ $\rho_0$ is the density of the liquid

The viscous force: $F_D = 6\pi\eta rv = 3\pi\eta dv$ (R>>>r)

The balance of forces is illustrated in Figure 10.2. Equating the balanced forces yields:

$$F_G = F_B + F_D$$

$$F_D = \frac{1}{6}\pi d^3(\rho - \rho_0)g$$

$$3\pi\eta d v_t = \frac{1}{6}\pi d^3(\rho - \rho_0)g$$

$$\boxed{\eta = \frac{g}{18}(\rho - \rho_0)\frac{d^2}{v_t}}$$ Plot $d^2$ vs. $v_t$ and determine the slope.

The coefficient $\eta$ is determined by changing the sphere, i.e. the diameter d, and hence the terminal velocity and to plot the $d^2$ vs. $v_t$ .

## Procedure:

(A) Measure the terminal velocity:

1- Select some balls bearing the same diameter.
2- Drop one ball and use the stopwatch to find the time it takes the ball to traverse the required distance.
3- Change the distance and repeat step 2 for a different distance than the one used in step2
4- Tabulate your data in the table.

(B) Determine the viscosity coefficient of the liquid.

1- Choose a fixed distance to use each time.
2- Select 6 spheres of different diameters and measure their diameters using a micrometer.
3- Drop the sphere in liquid and use the stopwatch to find the time
4- Record your data in the table.

**Exp. No.11**
**The Viscosity**

Name: ……………………………………….……...................….Grade: ……………………………

Student's No.: ……………………………………................… Day and Date: ………………………

Partners Names: …………………………….................…………..................... Sec: ………………

**Part 1:** to show that a small sphere falls with a constant terminal velocity.
Construct a velocity-time graph and a velocity-distance graph. These will show the ball bearing accelerating until it reaches terminal velocity.

| h(cm) | $t_1$ (sec) | $t_2$ (sec) | $t_3$ (sec) | $\overline{t}$ (sec) | $v=h/\overline{t}$ cm/sec |
|---|---|---|---|---|---|
| | | | | | |
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Plot h vs $\overline{t}$ and determine $v_t$

**Part 2:** Determination of the coefficient of viscosity:
Repeating the experiment with ball bearings of different mass and diameter will show that the terminal velocities of different bodies are different.

**Sphere density = 7.8 gm/cm$^3$**
**Liquid density = 1.12 gm/cm$^3$ h =50 cm**

| d(cm) | $d^2$ | $t_1$ (s) | $t_2$ (s) | $t_3$ (s) | $\overline{t}$ (s) | V | η |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
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Plot a graph of $d^2$ vs. $v_t$ . From the graph,

Determine the coefficient of viscosity.

The slope $= S =$

The coefficient of viscosity $\eta$ =

What is the unit of $\eta$: