FALLING BALL VISCOMETER

AIM

The purpose of this experiment is to measure the viscosity of unknown oil with a falling ball viscometer.

PRINCIPLE

The principle of the viscometer is to determine the falling time of a sphere with known density and diameter within a fluid filled inside glass tube. The viscosity of the fluid sample is related to the time taken by the sphere to pass between two specified lines on the cylindrical tube.

APPARATUS

Figure 1 is a schematic of a falling ball viscometer. A sphere of known density and diameter is dropped into a large reservoir of the unknown fluid. At steady state, the viscous drag and buoyant force of the sphere is balanced by the gravitational force. In this experiment, the speed at which a sphere falls through a viscous fluid is measured by recording the sphere position as a function of time. Position is measured with a vertical scale (ruler) and time is measured with a stopwatch.

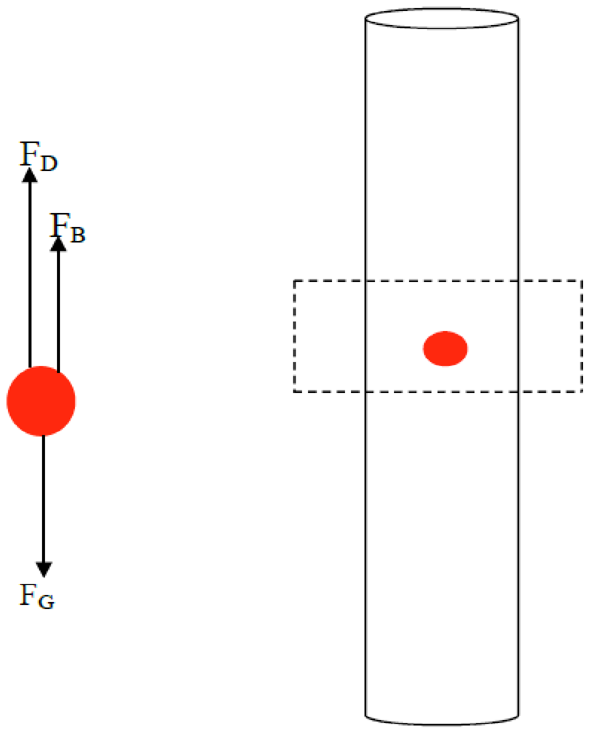

Figure 1. Body diagram for the falling ball viscometer

THEORY

Velocity of the sphere which is falling through the tube is dependent on the viscosity of the fluid. When a sphere is placed in an infinite incompressible Newtonian fluid, it initially accelerates due to gravity. After this brief transient period, the sphere achieves a steady settling velocity (a constant terminal velocity). For the velocity to be steady (no change in linear momentum), Newton's second law requires that the net forces acting on the sphere (gravity (F_G), buoyancy (F_B), and fluid drag (F_D) balance) equals to zero. All these forces act vertically are defined as follows:

Gravity : $F_G = -\frac{\pi}{6}\rho_p d_p^3 g$

Buoyancy : $F_B = +\frac{\pi}{6}\rho_f d_p^3 g$

Fluid Drag : $F_D = \frac{\pi}{8}\rho_f V_p^2 d_p^2 C_D$

Where ρ_p is the density of the solid sphere, ρ_f is the density of the fluid, d_p is the diameter of the solid sphere, g is the gravitational acceleration (9.8 m/s^2), V_p is the velocity of the sphere, and C_D is the drag coefficient. The particle accelerates to a steady velocity when the net force acting on sphere becomes zero:

$F_G - F_B - F_D = 0.$

The drag force acts upwards and is expressed in terms of a dimensionless drag coefficient. The drag coefficient is a function of the dimensionless Reynolds number, Re. The Reynolds number can be interpreted as the ratio of inertial forces to viscous forces. For a sphere settling in a viscous fluid the Reynolds number is

$$Re = \frac{\rho V_p d_p}{\mu}$$

where μ is the viscosity of the fluid. If the drag coefficient as a function of Reynolds number is known, the terminal velocity can be calculated. For the Stokes regime, Re<1, the drag coefficient can be determined analytically. In this regime, $C_D = \frac{24}{Re}$ and the settling velocity is

$$V_p = \frac{g d_p^2(\rho_p - \rho_f)}{18\mu}$$

The falling ball viscometer requires the measurement of a sphere's terminal velocity, usually by measuring the time required for sphere to fall a given distance. In this experiment, we measure the position of a sphere as a function of time and determine the steady state settling velocity. From this, we can calculate the viscosity from below equation given. For Reynolds number (Re<1), the equation of viscosity would be

$$\mu = \frac{g d_p^2\left(\rho_p - \rho_f\right) t_p}{18L}$$

Regardless of the Re, the settling velocity depends on the sphere diameter, the sphere density, the fluid density and the gravitational constant.

PROCEDURE

Measure the diameter of the sphere. Measure it multiple times to gain an accurate measurement and to determine the relative error in the measurement.

The viscosity can be determined by measuring the position of the sphere as a function of time as it settles through the unknown fluid.

For each sphere

1. Place the sphere near the top of the fluid reservoir. Try to get the sphere as close as possible to the air-fluid interface.

2. Release the sphere and start the stopwatch as soon as the sphere reaches the top line marked on the glass tube and stop it as it reaches the bottom marked line.

3. As the sphere settles, record its position as a function of time. (it may be more efficient to have one person drop the sphere, one person run the stopwatch, and the third to read the time off the stopwatch).

Observation:

1. Density of sphere = 2500 Kg/m^3.
2. Density of fluid = 956.1 Kg/m^3.

OBSERVATION TABLE

Sr. No	**Ball Dia (m)**	**Ball Density (kg/m^3)**	**Ball Reynolds number N_{Re}**	**Terminal velocity, V_p, m/s**	**Viscosity μ, Kg/m-s**	**Standard Deviation**
1						
2						
3						
4						
5						
Average						

Calculation Table:

S NO.	Distance (m)	Time (Sec.)
1		
2		
3		
4		
5		
Average		

CONCLUSION/DISCUSSION ON THE RESULT:

1. Write down the observations.
2. Try to explain the results from theory studied earlier.

FURTHER READING

1. Introduction to Fluid Mechanics 8th Edition, by *Fox, Robert W. and McDonald,* Alan T. , Chapter 1, PROBLEM NO. 1.2

TEACHING ASSISTANT: