الجمهـورية الجزائرية الديمقــراطية الشعبيـــة
Democratic Republic of Algeria وزارة التعليم العالي والبحث العلمي
البحث العلمي People's
Ministry of Higher Education and Research

Msila University

Faculty of Technology

Semester 03 – LMD – Civil Engineering

Fluid Mechanics Practical Work

PW N° 2: Measuring the viscosity of liquids (Falling ball viscometer)

1. Learning Objectives

Determine the dynamic and kinematic viscosity of a fluid by measuring the rate at which a small diameter steel and plastic ball falls through the fluid

2. Theoretical reminders

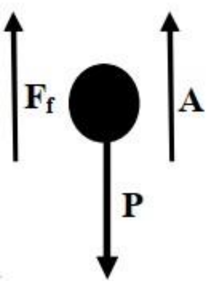
George Stokes was interested in the frictional force that a viscous flow produces around a sphere. He considered the case where the flow is governed by viscosity.
Stokes found that a stationary sphere of radius r, immersed in a viscous liquid in steady flow, experiences a frictional force, called the friction force $\boldsymbol{F_{friction}} = 6\pi\, r.\mu.V_{velocity}$.
Where V represents the flow velocity relative to the sphere and away from the sphere. This law is verified provided that the flow regime is governed by viscosity. There is a number that can be used to measure the more or less viscous nature of the flow: the Reynolds number $Re = \rho.v.d/\mu$

- $Re < 1 \Rightarrow$ *Viscous flow*
- $Re > 1 \Rightarrow$ *No viscous flow*
-

The Stokes formula is only valid if $\boldsymbol{Re < 1}$

Consider the problem of a ball falling into a fluid at rest in the laboratory frame of reference.
Let's balance the forces acting on the ball.
A ball of radius r falls into a fluid. The forces acting are:

The weight P of the ball: $P = m_{ball}.g = \rho_{ball}.V_{ball}.g$



m = mass of the ball kg;
V = volume of the ball m^3;
ρ = volumetric mass of the ball kg/m^3.

Archimedes principal: $A = \rho_{liquid}\, V_{ball}.g$.

The viscous friction force F_f given by the stockes formula: $\boldsymbol{F_{friction}} = 6\pi\, r.\mu.V_{velocity}$

r = radius of the ball;
v = falling speed of the ball;
μ = dynamic viscosity of the liquid.

When the ball reaches its limit falling speed (maximum speed): its movement is then uniformly rectilinear. The principle of dynamics gives

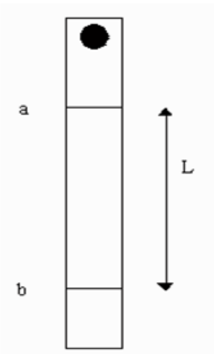
$$\sum \vec{F}ext = \vec{0} \Rightarrow P - FA - Ff = 0$$

$$\Rightarrow \rho_{\text{ball}} \times V_{\text{ball}} \times g - \rho_{fluid} \times V_{\text{ball}} \times g - 6\pi \times r \times \mu \times V_{Velocity} = 0$$

$$\boldsymbol{\mu} = (\rho_{\text{ball}} - \rho_{fluid} \times V_{\text{ball}} \times \text{g}) / \, 6\pi \times r \times V_{Velocity}$$

3. Equipment Used
- A falling ball viscometer;
- An electric balance;
- A stopwatch;
- A plastic sphere;
- A steel sphere;
- A caliper;
- A test tube.

4. Experimental procedure
A falling ball viscometer is a very simple device to set up. It consists of a long transparent tube of diameter D which has two reference lines A and B. The vertical tube is filled with the fluid to be studied, into which a spherical ball of mass m and diameter d sufficiently small compared to the diameter of the test piece D falls.



To determine the dynamic viscosity of two liquids (water, oil), we follow these steps:
- We release the ball, without initial velocity, into the cylindrical test tube.
- Using a stopwatch, we measure the time taken for the ball to fall Δt between the two reference points A and B, which are separated by (L = 30 cm), which allows us to calculate the ball's velocity and determine the dynamic viscosity by applying the equation shown above.

5. Work requested

1- Calculate the volume of the ball and the volumetric mass of the ball;
2- Calculate the dynamic viscosity of the two liquids;
3- Calculate the kinematic viscosity;
4- Conclude.

Table.1

Mass of ball (Kg)	*Volume of ball (m^3)*	*Volumetric mass of ball (Kg/m^3)*	*Volumetric mass of fluid (Kg/m^3)*
			1000
			920

Table.2 ***Plastic*** *sphere in* ***Water***

Experience	*Time Δt (s)*	*Velocity $v = L/t$ (m/s)*	*Dynamic viscosity $\mu (Pa.s)$*	*Kinematic viscosity $\nu = \mu / \rho_{fluide}$*
1				
2				
3				

Table.3 ***Plastic*** *sphere in* ***Oil***

Experience	*Time Δt (s)*	*Velocity $v = L/t$ (m/s)*	*Dynamic viscosity $\mu (Pa.s)$*	*Kinematic viscosity $\nu = \mu / \rho_{fluide}$*
1				
2				
3				

Table.4 ***Steel*** *sphere in* ***Water***

Experience	*Time Δt (s)*	*Velocity $v = L/t$ (m/s)*	*Dynamic viscosity $\mu (Pa.s)$*	*Kinematic viscosity $\nu = \mu / \rho_{fluide}$*
1				
2				
3				

Table.5 ***Steel*** *sphere in* ***Oil***

Experience	*Time Δt (s)*	*Velocity $v = L/t$ (m/s)*	*Dynamic viscosity $\mu (Pa.s)$*	*Kinematic viscosity $\nu = \mu / \rho_{fluide}$*
1				
2				
3				