MEASUREMENT OF THE DYNAMIC VISCOSITY OF A LIQUID

A LITTLE BIT OF THEORY...

FLUID

In physics, a fluid is a substance that continually deforms (flows) under an applied shear stress. Fluids include liquids, gases and plasmas.

VISCOSITY

The viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress. For liquids, it corresponds to the informal concept of "thickness"; for example, honey has a much higher viscosity than water

WATER HONEY

A SMALL SPHERE FALLING THROUGH A VISCOUS LIQUID

Stokes' law

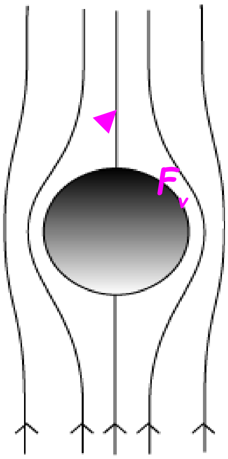
In 1851, *George Gabriel Stokes* derived an expression for the frictional force exerted on little spherical objects moving slowly through a viscous fluid.

The frictional force on a little sphere falling through a viscous liquid is given by

$$F_V = 6\pi R\eta v_s$$

where:

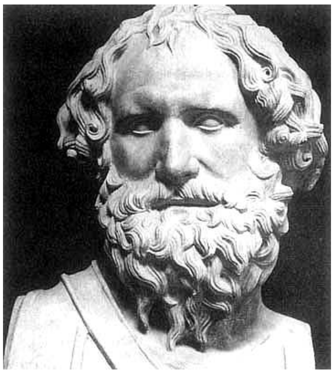
- F_V is the frictional force acting on the interface between the liquid and the particle
- η is the dynamic viscosity of the liquid
- R is the radius of the sphere
- v_s is the velocity of the sphere



THE FRICTIONAL FORCE IS PROPORTIONAL TO THE VELOCITY OF THE FALLING SPHERE!!!

Archimedes' principle

Archimedes' principle states that the upward buoyant force that is exerted on a body immersed in a fluid is equal to the weight of the fluid that the body displaces and acts in the upward direction.
Buoyancy = weight of displaced fluid.

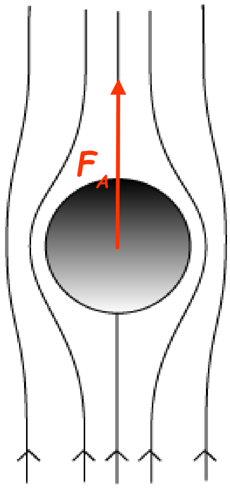


Buoyancy exerted by a liquid on a fully submerged sphere is given by

$$F_A = d_L V g$$

where:

- F_A is the upward buoyant force
- d_L is the density of the liquid
- V is the volume of the sphere $V = \frac{4}{3}\pi R^3$
- g is the gravitational acceleration



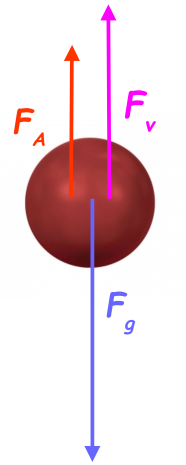
SCHEMATIC REPRESENTATION OF THE FORCES APPLIED TO A FALLING SPHERE IN A VISCOUS LIQUID

Three forces act to the falling sphere:

- GRAVITY FORCE $F_g = mg$
where m is the mass of the sphere

- BUOYANCY $F_A = d_L V g$

- FRICTIONAL FORCE $F_V = 6\pi R \eta v_s$



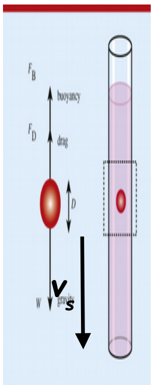


Figure 1. Schematic representation of the forces applied to the falling ball in the liquid.

If the little sphere is allowed to slowly descend through a sufficiently viscous liquid in a vertical glass tube, in a short time you have:

$F_g = F_A + F_V$ AND THE SPHERE REACHES CONSTANT VELOCITY!!!!

CAN YOU GIVE A BRIEF EXPLANATION OF THAT?

Measure the constant velocity v_s *of the descending sphere*, its radius R and its mass m, the gravitational acceleration g and the density d_L of the liquid and derive the value of η

$$F_g = F_A + F_V \longrightarrow mg = d_L V g + 6\pi R \eta v_s$$

YOUR GOAL IS TO DERIVE THE DINAMIC VISCOSITY η

SPLIT UP IN 2 GROUPS OF SIX

GROUP I: MEASURE v_s AND d_L

GROUP II: MEASURE g

Answer the "green questions" you will find here and there (you have just met one), take photos of the various steps and take notes of what you observe because you will need all this to prepare your final presentation!!

GROUP I

MEASUREMENT OF THE VELOCITY v_s OF A LITTLE SPHERE FALLING IN A VISCOUS LIQUID

Context

A body is said to have uniform velocity if it covers equal distance in equal intervals of time in a particular direction, however the time intervals may be small.

The uniform velocity of an object can be measured by calculating the constant ratio between the displacement **Δx** of the object in a certain time interval Δt and the time interval **Δt**

$$v=\frac{\Delta x}{\Delta t}$$

Equipment:

- 3 graduated cylinders
- 3 different liquids (water, seed oil, glycerin)
- many different little spheres
- a chronometer (you have it in your mobile phone)
- two rulers

Suggestions:

- Before starting the measurement, carry out tests to choose the liquid and the sphere
- Make sure that the sphere is completely immersed when you let it go into the liquid

DON'T FORGET TO MEASURE THE DIAMETER AND THE MASS OF THE SPHERE !!!!!

IS THE VELOCITY OF THE FALLING SPHERE REALLY CONSTANT?
HOW CAN YOU BE SURE OF THIS?

WHAT ARE THE MAIN SOURCES OF MEASUREMENT UNCERTAINTY IN THE EXPERIMENT? CAN YOU QUANTIFY THEM?

Pay special attention to your response time!!

MEASUREMENT OF THE DENSITY d_L OF THE LIQUID

Context

The density of a substance is its mass per unit volume. It can be measured by calculating the constant ratio between the mass ***m*** of the substance and its volume ***V***

$$d=\frac{m}{V}$$

Equipment:

- the chosen liquid
- one of the graduated cylinders
- two scales
- a caliper

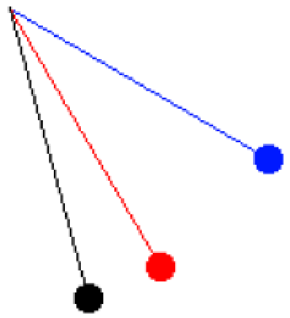
WHAT ARE THE MAIN SOURCES OF MEASUREMENT UNCERTAINTY IN THE EXPERIMENT? CAN YOU QUANTIFY THEM?

GROUP II:

MEASUREMENT OF THE GRAVITATIONAL ACCELERATION *g*

METHOD I

Context



If you suspend a mass at the end of a piece of string, you have a simple pendulum. It was Galileo who first observed that, for **small angles** of oscillation, the time ***T*** a pendulum takes to swing back and forth (called **period)** depends only on the length of the pendulum ***L*** and on the gravitational acceleration ***g***. **With the assumption of small angles, all simple pendulums should have the same period regardless of their initial angle !!!.** The relationship between ***T***, ***L*** and ***g*** is given by:

$$T=2\pi\sqrt{\frac{L}{g}}$$

Equipment:

- 10 m string
- a fishing lead
- a 5 m measuring tape
- a chronometer (you have it in your mobile phone)
- a ladder step

Suggestion:

- If you want to slow down the pendulum, to have more time to measure one or more periods, increase the length of the string

IS THE ASSUMPTION OF SMALL ANGLES CORRECT IN YOUR EXPERIMENT? HOW CAN YOU BE SURE OF THIS?

WHAT ARE THE MAIN SOURCES OF MEASUREMENT UNCERTAINTY IN THE EXPERIMENT? CAN YOU QUANTIFY THEM?

METHOD II

Context

If you drop an object from a height ***h*** with initial velocity equal to zero and the effect of air resistance can be neglected, the vertical motion of the object under gravity can be described by the equation of motion:

$$h=\frac{1}{2}gt^2$$

where ***t*** is the time interval taken by the object to reach the ground and ***g*** is the gravitational acceleration

Equipment:

- 10 m string
- a 5 m measuring tape
- a chronometer (you have it in your mobile phone)
- a little bouncy ball

Suggestion:

- You can drop the bouncy ball from the upper floor of a safety ladder (***h*** of about 8 m). Ask the teacher for assistance to find them!!

WHAT ARE THE MAIN SOURCES OF MEASUREMENT UNCERTAINTY IN THE EXPERIMENT? CAN YOU QUANTIFY THEM?

Pay special attention to your response time!!

HOW MUCH DO THE VALUES OF *g* DIFFER FROM THE VALUE YOU CAN FIND ON THE WEB?

ENJOY YOUR WORKSHOP!!!!