Exercise 8	DETERMINATION OF VISCOSITY OF FLUID BY STOKES' LAW

Measurement procedure

1. List of equipment

- Cylindrical tank with examined fluid
- Aerometer
- Set of balls
- Scales
- Micrometric screw
- Ruler with millimeter scale
- Stopwatch
- Höppler Viscometer

2. Goals

- Observation of bodies' falling motion in a continuous medium.
- Determination of fluid viscosity.

3. Measurement setup

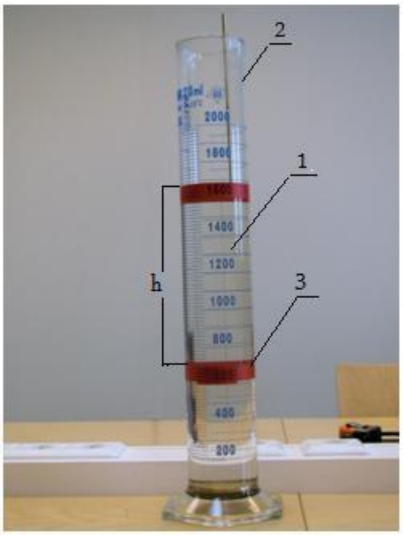

Fig.1. Device for measurement fluid viscosity by using Stokes' method:

1 – fluid
2 – glass cylinder
3 – rings
h – distance between rings

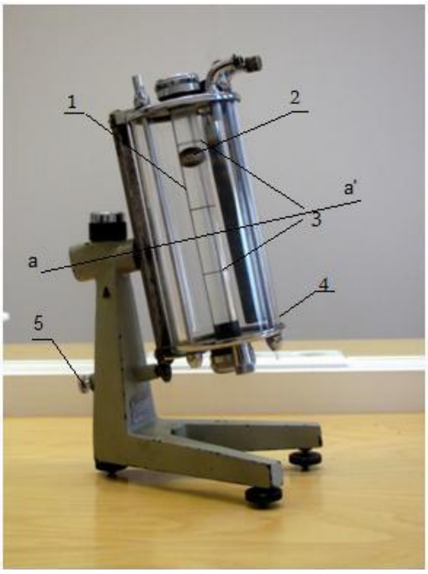

Fig.2. Höppler's viscometer:

1 – tube
2 – ball
3 – markers, between which the time of falling ball is measured
4 – thermostatic shield
5 – blocking device

4. Measurements

Wide cylindrical glass tank

a) Perform measurements for a few balls, check first if they sink.
b) Thoroughly clean every ball, then weigh each of them.
c) Measure the diameter of each ball by a micrometric screw; the diameter ought to be measured at least 10 times in different directions.
d) Use a ruler to measure the distance h between the rings on cylinder; upper ring should be at least 6 cm below fluid surface; the distance between rings is equal to path h travelled by balls with constant speed.
e) Measure the time t of each ball falling over the distance h at least 10 times. Balls should be dropped right above the fluid surface, near to the cylinder axis.
f) Measure the fluid density ρ_c by using an aerometer.

Höppler's viscometer

Do not dismantle the viscometer!!!
Do not insert anything into the viscometer!!!

a) Level the viscometer.
b) Assume the ball temperature as the ambient temperature; measure the time of the fall between markers for at least six times.
c) Perform measurement by releasing the blocking device and rotating the tube with thermostatic shield by 180 degrees.

5. Results analysis

a) for a wide cylinder:
1. Calculate the mean diameter $\bar{d}$ of each ball and the measurement uncertainty $u(\bar{d})$.
2. Calculate the mean falling time $\bar{t}$ between rings for each ball and measurement uncertainties $u(\bar{t})$.
3. Calculate each ball density ρ_k using formula (1) and their uncertainty $u_c(\rho_k)$.

$$\rho_k = \frac{6m}{\pi \cdot d^3} \qquad (1)$$

4. Calculate the fluid viscosity η using the formula below and its uncertainty $u_c(\eta)$.

$$\eta = \frac{d^2 \cdot g \cdot t \cdot (\rho_k - \rho_c)}{18h} \qquad (2)$$

5. Calculate the mean viscosity $\bar{\eta}$ for all measurements.
6. Calculate the uncertainty of viscosity $u(\bar{\eta})$ (using standard deviation).

b) for Höppler viscometer
1. Calculate the mean time of falling $\bar{t}$ and its uncertainty $u(\bar{t})$.
2. Calculate the fluid viscosity at room temperature and its uncertainty, using the formula:

$$\eta = k \cdot (\rho_k - \rho_c) \cdot t \qquad (3)$$

<u>Data required for calculations</u>

- for the viscometer with **glass** ball
$k = 0{,}7941 \cdot 10^{-6}\ m^2/s^2$

- for the viscometer with **metal** ball:
$k = 0{,}1216 \cdot 10^{-6}\ m^2/s^2$

ρ_k = (2,41 ± 0,01) g/cm^3 ρ_c = (1,261 ± 0,005) g/cm^3

ρ_k = (8,12 ± 0,01) g/cm^3 ρ_c = (1,261 ± 0,005) g/cm^3

6. Additional information

The time of student reaction while turning the stopwatch on and off should be accounted for while calculating the time uncertainty $u(t)$.

7. Proposed tables (to be confirmed by teacher)

Table 1. Measurements of balls' parameters and times of falling with calculated viscosity.

Ordinal	***m*** 10^{-3}[kg]	***d*** 10^{-3}[m]	***h*** [m]	***t*** [s]	ρ_k [kg/m^3]	ρ_c [kg/m^3]	η [Ns/m^2]
1							
2							
3							
⋮							
n							
$\acute{X}$							
ΔX							
$u(X)$							
$u_c(X)$							

$\overline{\eta}$ = $u\left(\overline{\eta}\right)$ =

Table 2. Measurements of parameters and times of falling with calculated viscosity measured on Höppler viscometer.

Ordinal	***t*** [s]	***k*** [m^2/s^2]	ρ_k [kg/m^3]	ρ_c [kg/m^3]	η [Ns/m^2]
1					
2					
3					
…					
n					
$\acute{X}$					
ΔX					
$u(X)$					
$u_c(X)$					