Exercise 12
Viscosity coefficient

Aim

To investigate the viscosity coefficient of the liquid using the Stoke's method .

Required theoretical knowledge

Viscosity, viscosity coefficient (units), laminar and turbulent motion of the liquid, Archimedes Law, forces acting on a sphere falling in a viscous fluid, equation of this motion and its solution, viscosity force, Reynolds number, sphere's velocity versus time, the rule of propagation of uncertainties, the standard deviation.

Equipment

Glass cylinder filled with the viscous liquid (paraffine oil), a glass burette with a volumetric scale, small tank for the destilled water, stopwatch (Fig. 1).

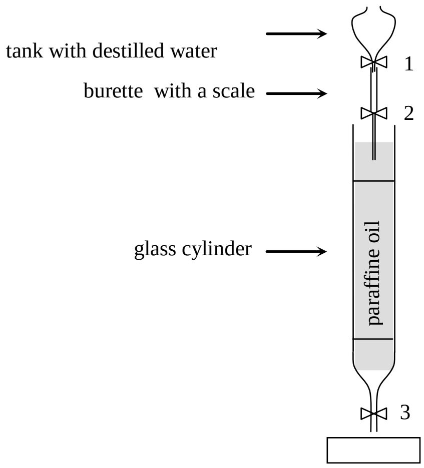

Fig. 1. Measurement setup.

Problems for discussion:

What is viscosity?
Which forces act on sphere falling in a viscous fluid?
Archimeded law.

Measurement plan:

1. Set the distance *L* between two black horizontal marks on a glass cylinder to value between 25 and 40 centimeters,
2. Using the valve 1, fill in carefully a burette with distilled water to the level about 1 cm above the top red line (the space between the red lines in the burette contains 20 cm^3 of water),
3. Slowly open the valve 2 at the bottom of the burette and form big water drops falling slowly and continuously down in the paraffin oil; hurry up – you can use for this purpose only the excess of water above red top line; end of the burette must be submerged in oil.

4. When water in the burette reaches the top red line, start counting the number of water drops that can be formed from the volume of 20 cm^3 of water in the burette; be careful – don't change the position of valve 2 during counting,
5. Your collegue should simultaneously measure with a stop watch the time of falling between the black marks on a glass cylinder for 10 subsequent water drops;
6. When you finish counting the drops, close the valve 2
7. Repeat the experiment for another water flow implied by another position of the valve 2.

Problems for discussion:

What is the Reynolds number?
Describe the motion of the sphere in the fluid.

Data processing:

1. On the basis of measurement data, calculate the average radius of the drops
2. Calculate the viscosity coefficient η using formula:

$$\eta = \frac{2(\rho_k - \rho) r^2 g t}{9L(1 + 2.4\frac{r}{R})} \qquad (1)$$

where: ρ_k – density of water drop, ρ– density of oil equals 0,80 g/cm^3, r – average drop radius, g – gravitational acceleration, t – average time of falling of water drops; L – the distance which the water drop passes ; let's take the diameter of cylinder equal to *2R = 4.5 cm*.

3. Find uncertainty of viscosity coefficient using the rule of propagation of uncertainties. For calculations of viscosity coefficient η uncertainty use the equation (1) without the correction factor $2.4\frac{r}{R}$ that expresses the influence of cylinder walls on the motion of drops. Take into account uncertainties of *t*, *r*, *L*. Find the uncertainty of *t* using the standard deviation, expressed by the equation:

5. Calculate the Reynold's number $\mathrm{Re} = \frac{v \cdot 2r \cdot \rho}{\eta}$ and its uncertainty

$$\Delta t = \sqrt{\frac{\sum (t_{sr} - t_i)^2}{n(n-1)}}$$

6. Compare viscosity coefficients for drops of water that differ from the size.

Literature

1. Halliday, Resnick "Fundamentals of Physics - 8th edition", John Wiley 2007,