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Physics Laboratory – Report #5

Experiment: 8

Determination of viscosity of fluid by Stokes' Law

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Introduction;

This report discusses the methods with which the viscosity of liquid glycerin is determined, and uses the data to validate Stokes' Law. Two experiments were performed: the viscosity of glycerin was determined using a rotational viscometer, and the data used to validate Stokes' Law was collected using a falling ball viscometer. Results showed that either method showed significant error and did not validate Stokes' Law; though the revised Stokes' Law equation gave much more accurate results for the viscosity determined from the falling ball viscometer.

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 higher viscosity than water.

Viscosity is a property of the fluid which opposes the relative motion between the two surfaces of the fluid that are moving at different velocities. It is related with the friction between the molecules of fluid. When the fluid is forced through a tube, the particles which compose the fluid generally move more quickly near the tube's axis and more slowly near its walls; therefore, some stress (such as a pressure difference between the two ends of the tube) is needed to overcome the friction between particle layers to keep the fluid moving. For a given velocity pattern, the stress required is proportional to the fluid's viscosity.

A fluid that has no resistance to shear stress is known as an ideal or inviscid fluid. Zero viscosity is observed only at very low temperatures in superfluids. Otherwise, all fluids have positive viscosity and are technically said to be viscous or viscid. A fluid with a relatively high viscosity, such as pitch, may appear to be a solid.

APPARATUS

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

References;

- https://www.odinity.com/stokes-law-reynolds-number-measuring-liquid-viscosity/
- https://physics.info/viscosity/summary.shtml

Data Table:

(gram)	weight(g)	unc(m)	vesel height(cm)		34.2
white	0.55	0.01			
grey	0.31	0.01	density(g/cm^3)		1.26
black	0.25	0.01			
blue	0.43	0.01			
time(second)	blue(sec)	white(sec)	black(sec)	grey(s)	
1	25.2	12.3	13.81	8.49	
2	24.93	11.86	13.82	8.55	
3	25.89	12.4	13.48	8.59	
4	24.97	12.48	13.01	8.05	
5	24.57	11.9	13.31	8.34	
6	25.06	12.1	13.88	8.17	
7	24.76	12.59	13.38	8.3	
8	25.08	12.19	13.52	8.5	
9	24.98	12.22	13.34	8.2	
10	24.67	12.47	13.73	8.41	
average	25.011	12.251	13.528	8.36	
unc(t)	0.9993706353	0.6729846457	0.7664637413	0.491426495	

Calculations;

1. Calculate the mean diameter $\overline{d}$ of each ball and the measurement uncertainty $u(\overline{d})$.

(mm)	blue(mm)	white(mm)	black(mm)	grey(mm)
1	7.94	7.93	5.93	5.95
2	7.95	7.94	5.91	5.95
3	7.93	7.96	5.99	5.96
4	7.94	7.93	5.92	5.96
5	7.71	7.97	5.93	5.95
6	7.69	7.98	5.92	5.95
mean	7.86	7.95	5.93	5.95

2. Calculate the mean falling time $\overline{t}$ between rings for each ball and measurement uncertainties $u(\overline{t})$.

time(s)	blue(s)	white(s)	black(s)	grey(s)
1	25.2	12.3	13.81	8.49
2	24.93	11.86	13.82	8.55
3	25.89	12.4	13.48	8.59
4	24.97	12.48	13.01	8.05
5	24.57	11.9	13.31	8.34
6	25.06	12.1	13.88	8.17
7	24.76	12.59	13.38	8.3
8	25.08	12.19	13.52	8.5
9	24.98	12.22	13.34	8.2
10	24.67	12.47	13.73	8.41
average	25.011	12.251	13.528	8.36
unc(t)	0.999	0.672	0.766	0.491

3. Calculate each ball density ρk and their uncertainty uc(ρk).

(mm)	blue(mm)	white(mm)	black(mm)	grey(mm)
unc(d)	0.253	0.043	0.058	0.010

4.), 5.), 6.)

Fluid viscosity is calculated for each time measurement using the avarage of radius measurements constant with the formula given in the theory.

g = 9807 mm/s^2

Example for White and time measurement “1”:

$$\frac{7{,}93^2 \cdot 9807 \cdot 14{,}13 \cdot (0{,}00188 - 0{,}00136)}{18 \cdot 356} = 0{,}701239(\frac{kg}{km \cdot sec})$$

Units are changed from mm and g to kg and km during the calculation.

For each 10 measurements viscosity is calculated. Afterwards, mean and standard diviation is calculated by the formulas;

$$\boldsymbol{u_A(x)} \equiv s_{\bar{x}} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n(n-1)}}$$

$$X \approx \bar{X} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

<u>All results are in the data tables.</u>

Uncertainties:

Standard diviation and the mean values of measurements are calculated by standard method;

$$\boldsymbol{u_A(x)} \equiv s_{\bar{x}} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n(n-1)}}$$

$$X \approx \bar{X} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Uncertainties of type A are calculated by standard diviation formula; for type B, only the resolution factor is considered.

$$u_A(t) = u_A(d) = \frac{0{,}01}{\sqrt{3}} \cdot (units)$$

Uncertainty of type A for radius (mm), time (s) and mass(g). All has resolution 0,01.

Total standard uncertainty;

$$\boldsymbol{u(x)} = \sqrt{u_A^2(x) + u_B^2(x)}$$

The results of this calculations are in the data tables, uncertainties title.

Density for each ball is calculated by the formula given in the theory by using the mean value of radius measurements.

Example:

For white, $\frac{6 \cdot 0{,}49}{\pi \cdot 7{,}93^3} \approx 0{,}001875444 \ (\frac{g}{mm^3})$

Example calculation for uncertainty for density:

$$\sqrt{(\frac{6\cdot u_m}{\pi\cdot \mathrm{d}^3})^2 + (\frac{6\cdot \mathrm{m}\cdot -3\cdot \mathrm{u}_d}{\pi\cdot \mathrm{d}^4})^2} = \sqrt{(\frac{6\cdot\frac{0,01}{\sqrt{3}}}{\pi\cdot 7,93^3})^2 + (\frac{6\cdot 0,49\cdot -3\cdot 0,0065}{\pi\cdot 7,93^4})^2} \approx 0.000023\,\frac{g}{mm^3}$$

u_d *comes from the data table, calculated earlier on the experiment.*

Conclusion:

Discussion

Results were as expected. The procedure of measurements were smooth and well prepared before the start of the experiment.

Results and the Uncertainty

The likely uncertainty that came from using stop watch is disregarded in the calculations due to inability of estimating the magnitute. It would be useful to note an estimation during the measurement.

Also the formula;

$$U_c(x) = ku_c(x)$$

can be applied to all uncertainties with k = 2. It is safe to assume there would be mistakes caused by the inexperiencedness of experiment team.