Viscous and Buoyant Forces

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Introduction

If a small sphere is dropped in a viscous fluid, it will accelerate until it reaches its terminal velocity, v_t, at which point it falls at a constant velocity. The reason for this is that the gravitational force is balanced by the buoyant and viscous forces. The buoyant force is due to the density of the viscous fluid and the viscous force is due to the viscosity of the viscous fluid.

The following expression qualitatively describes this system:

gravitational force = buoyant force + viscous force

with the quantitative expression given as:

$$m_s g = \frac{4}{3}\pi R^3 \rho g + 6\pi\mu R v_t,$$

where

m_s is the mass of the sphere in grams

g is the gravitational constant in cm/s^2

R is the radius of the sphere in cm

ρ is the density of the fluid in g/cm^3 (g/ml)

μ is the viscosity of the fluid in poise.

All of the constants but μ can be measured directly, thus μ can be calculated from the following equation:

$$\mu = \frac{1}{v_t}\left(\frac{m_s g}{6\pi R} - \frac{2}{9}R^2 \rho g\right)$$

Procedure

1. Get three spheres and obtain the mass of each. Take care to identify each sphere individually.
2. Measure the radius of each sphere.
3. Drop the sphere in a graduated cylinder of vegetable oil. Record the time it takes the sphere to fall from the tape to the bottom of the cylinder. Measure this distance.
4. Calculate the value of μ for vegetable oil.
5. Repeat steps 3 and 4 for corn syrup and water.

Data Table

	Vegetable Oil	Corn Syrup	Water
m_s			
D			
$R=D/2$			
time			
distance			
v_t = *distance/time*			
ϱ			
μ			

Questions (Use a separate piece of paper if necessary)

1. Fill in the data table completely. Show your work for calculating μ.

2. Draw a free body diagram showing all three forces acting on the sphere falling in a viscous fluid.

3. The viscosity of water is 1.0 centipoise. Is your estimate close to this value?

4. What are the sources of error for this experiment (list at least three)?