Memorial University of Newfoundland
Department of Physics and Physical Oceanography
Physics 2053 Laboratory

Viscosity of Sugar Solution

Introduction

In this experiment you will determine the viscosity of sugar solution at room temperature. Figure (1) shows two cylinders, one inside the other, where the space between them is filled with a liquid.

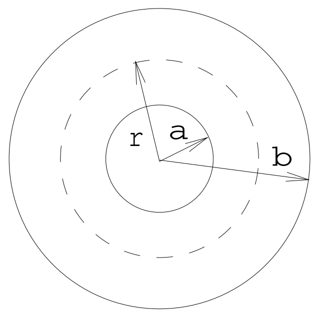

Figure 1: Diagram to show two concentric cylinders of radii a and b.

Now consider a cylinder of liquid between them, radius r. The surface area of this cylinder is $2\pi r\ell$, where ℓ is its length. If it rotates with angular velocity ω, the total drag on it will be $\eta.2\pi r\ell.rd\omega/dr$, where η is viscosity and $rd\omega/dr$ is the local rate of shear strain. This drag acts tangentially and gives rise to a torque τ, where

$$\tau = 2\pi\eta\ell r^3\frac{d\omega}{dr}. \quad (1)$$

This torque must be constant throughout the liquid under steady state conditions and equal to the torque applied to the moving cylinder. Hence

$$\int_a^b 2\pi\eta\ell d\omega = \int_a^b \tau\frac{dr}{r^3} \quad (2)$$

and thus

$$\eta = \tau\frac{(1/a^2 - 1/b^2)}{4\pi\omega\ell} \quad (3)$$

Method

1. A thin cord wound around the pulley at the top of the inner cylinder is fastened to a small mass which falls toward the ground when released. As it falls, the cylinder will rotate with angular velocity ω due to the applied torque (given by $\tau = mgr_p$, where r_p is the radius of the pulley). We assume that the load does not accelerate because the cylinder quickly reaches its terminal velocity.

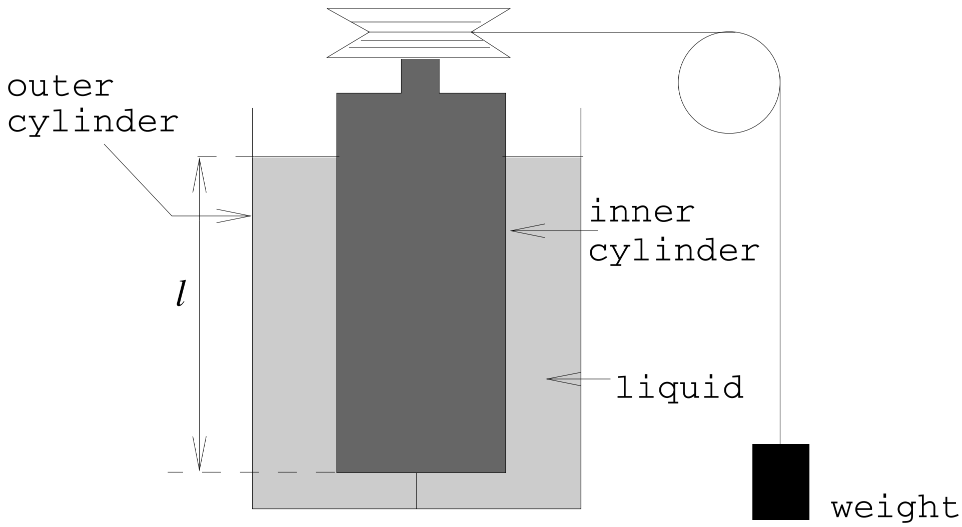

Figure 2: Schematic diagram of the viscosity of sugar apparatus

2. Eq (3) suggests that ω is necessary to determine viscosity. However, it is not necessary to calculate ω for each run: if you keep h constant by measuring the time, t, taken for the mass to fall a pre-determined distance (say, $^1\!/_2$ m), plotting a graph of $1/t$ versus m will give a straight line, the slope of which will allow you to determine the viscosity.

3. Fill the container with sugar solution until the inner cylinder is just submerged. Start with a low mass and measure the time for increasing masses up to a maximum load of about 100 g.

4. Plot your data on a suitable graph and determine the viscosity of the sugar solution at room temperature. Estimate the uncertainty in your result and compare your answer with the viscosities of other liquids such as water or machine oil.

5. The onset of turbulence is indicated when the graph deviates from linearity. (You may or may not be able to observe this.) Approximately, what applied torque does this point correspond to?
6. When you have finished, return the sugar solution to the bottle and thoroughly rinse the apparatus with warm water.
