EP07 the Coefficient of Viscosity

OBJECTIVE

1. To familiarize the student with the use of micrometer and vernier caliper
2. To measure the coefficient of viscosity of castor oil.

THEORY

Viscosity is a kind of internal friction exhibited to some degree by all fluids. Liquids such as engine and castor oil which pour slowly are more viscous than water. To measure coefficient of viscosity(η),Stokes'law is used. The expression of Stokes' law is:

$$F=6\pi\eta vr$$

The expression only holds for steady motion in a fluid of infinite extent (otherwise the walls and bottom of the vessel affect the resisting force).

Now consider the sphere falling vertically under gravity in a viscous fluid. Three forces act on it , Fig.1,

(i) its weight W, acting downwards,
(ii) the upthrust U due to the weight of fluid displaced, acting upwards, and
(iii) the viscous drag F, acting upwards.

The resultant downward force is *(W-U-F*) and causes the sphere to accelerate until its velocity is a constant, then the three forces reach balance, that is

$$W-U-F=0 \qquad (1)$$

The sphere then continues to fall with a constant velocity, known as its terminal velocity, suppose v_t. Now

$$W=\frac{3}{4}\rho\pi r^3 g \qquad \text{here } \rho \text{ is the density of the sphere} \qquad (2)$$

$$U=\frac{3}{4}\sigma\pi r^3 g \qquad \text{here } \sigma \text{ is the density of the fluid} \qquad (3)$$

Also, if steady conditions still hold when terminal velocity is reached then by stokes' law

$$F=6\pi\eta r v_t \qquad (4)$$

Using equations (1) (2) (3) and (4),we obtain

$$v_t=\frac{2r^2(\rho-\sigma)g}{9\eta} \qquad (5)$$

Here v_t is the terminal velocity, r and ρ*,* the radius and density of the sphere , and σ*,* the density of the liquid. The viscosity then can be calculated.

To satisfy as far as possible the assumption in stokes' law that the liquid is infinite in extent, the vessel of liquid must be wide compared with the diameter of a small ball (the later should be less than 3mm for a wide measuring cylinder); it should also be deep, Fig.2. The terminal velocity v_t is obtained by finding the average time *t* taken by balls of the same size to fall from mark A (which is far enough below the surface for the ball to have reached its terminal velocity at A) to mark B (which is not too near the bottom of the vessel). Then

$$v_t = L/t \quad \text{(suppose L=AB)} \qquad (6)$$

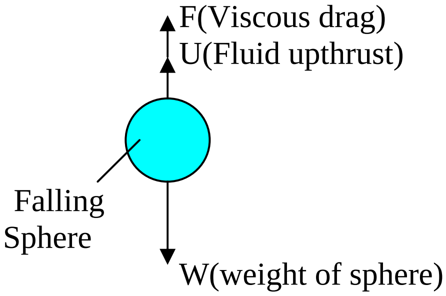

Fig.1

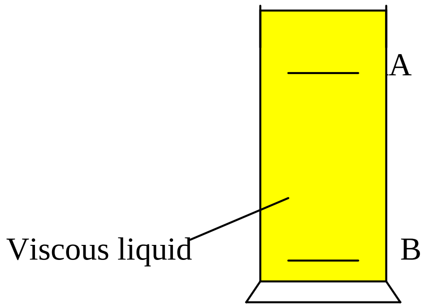

Fig.2

Substitute equation (6) into equation (5) , we can obtain the coefficient of viscosity η :

$$\begin{aligned}\eta &= \frac{2}{9}\frac{(\rho-\sigma)g}{L}r^2 t \ (r \text{ is the radius of the ball}) \\ &= \frac{(\rho-\sigma)g}{18L}d^2 t \ (d \text{ is the diameter of the ball})\end{aligned} \qquad (7)$$

Because the vessel of liquid is finite the affect of the vessel wall can't neglect and equation (7) should be modified. The modified equation is:

$$\eta = \frac{(\rho-\sigma)g}{18L}d^2 t\left(1-2.4\frac{d}{D}-3.3\frac{d}{2h}\right) \qquad (8)$$

PROCEDURE

1. Measure the temperature T, the density σ of the liquid, AB's length L, the height of the castor oil and the inner diameter of the vessel. Complete table1 .
2. Measure the diameter of the ball 1 three times.
3. Measure the time taken by the ball 1 falling from mark A to mark B three times.
4. Repeat 2 and 3 with ball 2 three times ,and complete table 2

DATA RECORDING AND PROCESSING

Table 1

T_{begin}=	T_{finish}=	$T_{average}$=
ρ_{ball}= g/cm^3	σ_{oil}= g/cm^3	L= cm
g= cm/s^2	D= cm	h= cm

Table 2

item / times	Ball 1			Ball 2		
	d_1(cm)	t_1(s)	η_1 (P)	d_2(cm)	t_2(s)	η_2 (P)
1						
2						
3						
Average						

$\eta_{reference}$ =

η_1 =

η_2 =