Experiment No. ….. Date: … /… /2080

TO DETERMINE THE COEFFICIENT OF VISCOSITY OF A LIQUID BY STOKES METHOD.

APPARATUS REQUIRED:

1. Experimental liquid (Glycerin)
2. A tall transparent jar (About 1 m tall)
3. Steel ball bearings (of different sizes)
4. A stop watch
5. A micro meter screw gauge
6. A meter scale
7. A thermometer
8. Rubber bands

THEORY:

The property of liquid by virtue of which it opposes the relative motion between its different layers is known as viscosity.

The force which tends to oppose the motion of layer over another is called as viscous force.

The Newton's formula for the viscous force (F) between two layers is:

$$F = -\eta\, A\, \frac{dv}{dx} \;\ldots\ldots\ldots\ldots (1) \qquad \text{[In magnitude]}$$

Where, $\eta = coefficient\ of\ viscosity.$

$A = area\ of\ contact\ between\ two\ layers\ .$

$\frac{dv}{dx} = velocity\ gradient\ between\ two\ layers.$

For $A = 1m^2$

$\frac{dv}{dx} = 1\ s^{-1}$,

$$\boldsymbol{\eta = F}$$

Thus, coefficient of viscosity (η) is defined as the tangential backward force per unit area of layer required to maintain unit velocity gradient between the layers.

Stoke's law:

According to stoke, if a sphere of radius r moves through a liquid or a fluid of viscosity η with a velocity $\boldsymbol{v}$ then the viscous force on the sphere is given by:

$$\boldsymbol{F_v = 6\pi\eta r v}$$: Stoke's formula for viscous force.

✓ The viscous force is velocity dependent force. $\boldsymbol{F_v \propto v}$.

When a solid body moves through a fluid, the fluid layer in contact with the solid moves with the velocity of solid. The layers away from solid move with decreasing velocity. Thus, a relative motion is created between different layers of fluid so that a viscous force acts on the body.

When a solid body falls through a viscous fluid, three forces come into play:

1. Weight of body (acting downward)
2. Upthrust (buoyancy0 due to fluid (acting upward)
3. Viscous force on body (acting upward- opposite of motion)

Initially, the body accelerates downward due to gravity (velocity increases and hence the viscous force also increases). After some time, a situation is reached at which the upward force (sum of viscous force and buoyancy) is equal to the downward force (weight of body). The body now falls downward with a constant velocity-called as terminal velocity $\boldsymbol{v_t}$. This means the falling object has reached its maximum velocity and acceleration is now zero.

The viscous force at this condition is written as:

$$\boldsymbol{F_v = 6\pi\eta r v_t}$$

Terminal velocity (v_t):

Terminal velocity is defined as the maximum (and steady) velocity attained by an object falling through a fluid.

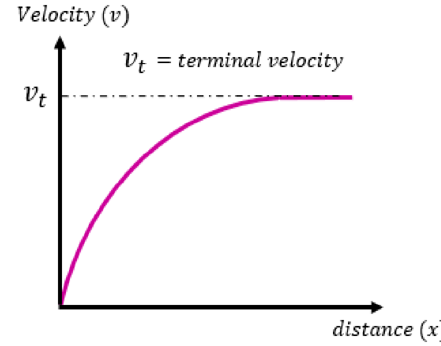


Figure: Variation of velocity of ball falling down a viscous fluid.

Expression for coefficient of viscosity from Stoke's method:

If a sphere of radius r and density ρ falls under gravity in a liquid of density σ at a constant velocity v_t, then

$$Total\ upward\ force = Total\ downward\ force$$

or, $$F_v + U = mg$$

or, $$6\pi\eta r v_t + \frac{4}{3}\pi r^3 \sigma g = \frac{4}{3}\pi r^3 \rho g$$

or, $$6\pi\eta r v_t = \frac{4}{3}\pi r^3 (\rho - \sigma) g$$

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

Expression for terminal velocity (if η is known)

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

Expression for coefficient of viscosity.

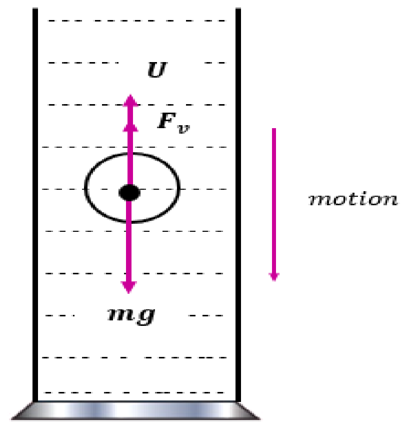


Figure: Motion of a solid ball in a viscous fluid

Working formula:

- To find terminal velocity (v_t):

  If, $d = distance\ travelled\ by\ the\ sphere\ inside\ the\ fluid\ at\ steady\ state$

  $t = time\ taken\ to\ travel\ then\ distance$

  Then, terminal velocity,

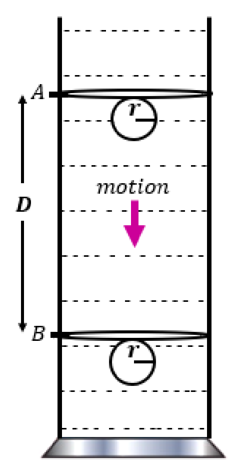
$$v_t = \frac{D}{t}$$

- To find the coefficient of viscosity of fluid (η)
  - ✓ The coefficient of viscosity is:

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

PROCEDURE:

1. Take a long transparent clean jar.
2. Fill the jar with a given experimental liquid (whose coefficient of viscosity has to be determined).
3. Mark two points A and B on the jar, as shown. Mark the point A at certain diatance below the surface of liquid so that when the ball reaches the point it would have acquired terminal velocity. Note the distance (D) between the points A and B.
4. Determine the diameter (and hence radius) of a ball bearing and drop it gently into the liquid. When the ball crosses the point A, start the stop watch and stop the watch when the ball crosses the point B. Note down the corresponding time.
5. Repeat the step 4 for other four different sized steel balls.



OBSERVATIONS:

Least count of micrometer screw gauge = ……………

Instrumental error of micrometer screw gauge = …………………

Least count of meter scale = …………………..

Least count of stop watch = ……………………

Density of solid ball, $\rho =$ ………………….. (mention the name of solid body)

Density of viscous liquid, $\sigma =$ …………………… (mention the name of liquid)

Observation Table:

- **To find the diameter of the steel balls:**

SN	Main scale reading $a\ (cm)$	Circular scale division C	Circular scale reading $b = C \times LC$ (cm)	Total reading $(\boldsymbol{Diameter})$ $d = a + b\ (cm)$	Corrected diameter $d\ (cm)$	Radius of steel ball $r\ (cm)$
1.						
2.						
3.						
4.						
5.						

- **To find the terminal velovity and coefficient of viscosity:**

SN	**Radius of steel ball $\boldsymbol{r}$ (cm)**	**Distance travelled by ball at steady state $\boldsymbol{D}$ (cm)**	**Time taken to travel distance D $\boldsymbol{t}$ (sec)**	**Terminal velocity $\boldsymbol{v_t = \frac{D}{t}\ (cm/s)}$**	**Coefficient of viscosity $\boldsymbol{\eta = \frac{2}{9}\frac{r^2\,(\rho - \sigma)g}{v_t}}$ $(\boldsymbol{poise})$**	**Mean $\boldsymbol{\eta}$**
1.						
2.						
3.						
4.						
5.						

CALCULATION

The mean value of coefficient of viscosity of the given liquid $\eta =$ ……………… $poise$.

$=$ ……………….

$=$ ………………. decapoise (Nsm^{-2}) (Pa s).

PERCENTAGE ERROR

Standard value of coefficient of viscosity of the given liquid = ………………..Nsm^{-2}

Observed value of coefficient of viscosity of the given liquid = ……………….. Nsm^{-2}.

$$Percentage\ Error = \left|\frac{Standard\ Value - Observed\ value}{Standard\ value} \times 100\%\right|$$

$$= \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$= \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

= …………….. %

RESULT:

The coefficient of viscosity of the given liquid (………………..) has been found to be ……………………. with …………. % error.

CONCLUSIONS:

Thus, the coefficient of viscosity of given liquid has been found experimentally in laboratory using stokes' method.

SOURCES OF ERROR

1. The ball used may not be perfectly spherical.
2. The time may not be measured correctly.
3. Temperature may vary.
4. The point from where taking the terminal velocity may not be found out.

PRECAUTIONS

1. The steel balls should be perfectly spherical and small.
2. The jar should be perfectly vertical.
3. The liquid should be highly viscous.
4. The balls should be dropped gently and carefully.
5. The ball should not touch the wall of the jar during its motion.
6. The liquid should be of uniform density.

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