



EXPERIMENT

AIM

To determine the coefficient of viscosity of a given viscous liquid by measuring the terminal velocity of a given spherical body.

MATERIAL REQUIRED

A screw gauge, stopwatch, clamp with stand, thermometer, transparent viscous liquid, a cylindrical glass pipe about 1.25 cm in length and 4 cm in diameter, a meter scale and thread, some steel balls of known diameter, two large corks and a cork borer.

THEORY

Viscosity is the property of a fluid by the virtue of which an internal resistance comes into play when the fluid is in motion and opposes the relative motion between its different layers.

TERMINAL VELOCITY

It is the maximum velocity acquired by the body, falling freely in a viscous medium.

Therefore, terminal velocity is given by:

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

COEFFICIENT OF VISCOSITY

Suppose a fluid flows over a fixed surface DC as shown in the figure. The upper layers of the fluid move with some increasing velocity while the layer of the fluid in contact with surface DC does not move. So, due to this, a dragging force F comes into action which acts tangentially to every layer. This force depends upon the following factors:

- (i) It is directly proportional to the area of layers, i.e. $F \propto A$.
- (ii) It is directly proportional to the velocity gradient between the two layers, i.e. $F \propto \frac{dv}{dx}$.

On combining, we get

$$F \propto \frac{Adv}{dx}$$

$$F = \frac{-\eta Adv}{dx}$$

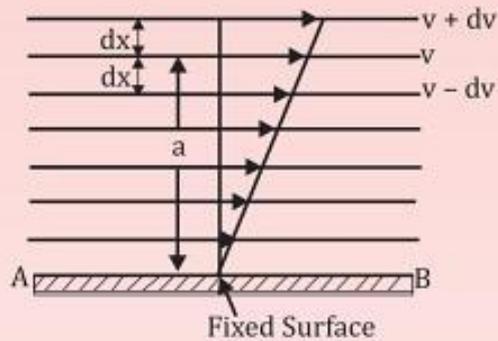
i.e.

$$\eta = \frac{-F}{A \frac{dv}{dx}}$$

Where, η is called coefficient of viscosity and the negative sign shows that the force is acting in the opposite direction of velocity.

Thus, coefficient of viscosity is defined as the tangential force required to maintain a unit velocity gradient between the two layers each of unit area.





S. I. unit of coefficient of viscosity is newton/second meter⁻² (N-sm⁻²) or poise (P) and dimensional formula is (ML⁻¹T⁻¹).

STOKE'S LAW

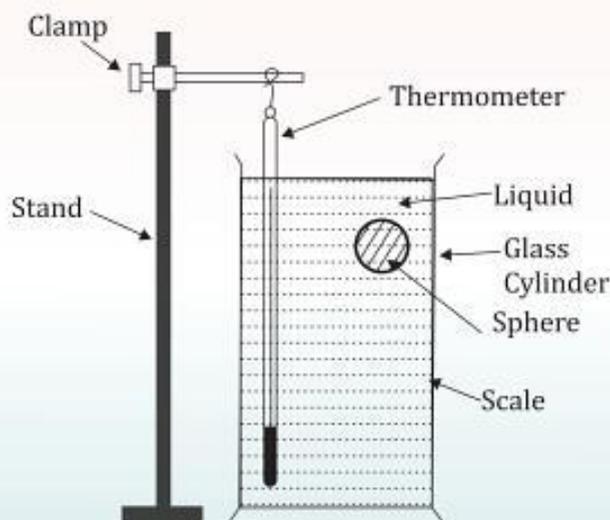
Sir George G Stokes, an English scientist found that the backward dragging force F acting on a small spherical body of radius r , moving through a fluid of coefficient of viscosity η with velocity v is given by,

$$F = 6\pi r\eta v$$

So, this is called **Stoke's law**.

PROCEDURE

1. Clean the glass jar and fill it with the viscous liquid, which must be transparent.
2. Check that the vertical scale along the height of the jar is clearly visible. Note its least count.
3. Test the stop clock/watch for its tight spring. Find its least count and zero error (if any).
4. Find and note the least count and zero error of the screw gauge.
5. Determine the mean radius of the ball.
6. Drop the ball gently in the liquid. It falls in the liquid with accelerated velocity for about one-third of the height of liquid. Then, it falls with uniform terminal velocity.
7. Start the stop clock/watch when the ball reaches some convenient division (20 cm; 25 cm;). Note its fall.
8. Stop the stop clock/watch just when the ball reaches lowest convenient division (say 45 cm).
9. Find and note the distance fallen and time taken by the ball.
10. Repeat steps 6 to 9 two times more.



- Note and record the temperature of the liquid.
- Record your observations as given ahead.

OBSERVATIONS

Least count of vertical scale	=	1 mm.
Least count of stop-clock/watch	=	___ s
Zero error of stop-clock/watch	=	___ s
Pitch of the screw gauge (p)	=	1 mm
Number of divisions on the circular scale	=	100
Least count of screw gauge (L.C.)	=	$\frac{1}{100} = 0.01$
Zero error of screw gauge (e)	=	___ mm
Zero correction of screw gauge (c)	=	$(-e) =$ ___ mm

Diameter of spherical ball

(i) along one direction,	$D_1 =$	___ mm
(ii) In perpendicular direction,	$D_2 =$	___ mm

Terminal velocity of spherical ball

Distance fallen,	$S =$	___ cm
Time taken,	$t_1 =$	___ s
	$t_2 =$	___ s
	$t_3 =$	___ s

CALCULATIONS

Mean diameter,	$D = \frac{D_1 + D_2}{2} =$	___ mm
Mean radius,	$r = \frac{D}{2} =$	___ cm
Mean time,	$t = \frac{t_1 + t_2 + t_3}{3} =$	___ s
Mean terminal velocity,	$v = \frac{S}{t} =$	___ cms^{-1}
From formula,	$\eta = \frac{2r^2(\rho - \sigma)g}{9v} =$	___ C.G.S. units.

RESULT

The coefficient of viscosity of the liquid at temperature ($\theta^\circ\text{C}$) = ___ C.G.S. units.

PRECAUTIONS

- The steel balls used in the experiment must be perfectly spherical.
- The temperature of the liquid should be measured in the beginning as well as in the end of the experiment because it affects the viscosity of the fluid.
- The diameters should be measured in two mutually perpendicular directions.
- Noting down the velocity should be done when it becomes constant.
- The steel balls should fall without touching the sides of the tube and they should be wetted with the same viscous fluid as filled in the tube.

SOURCES OF ERROR

- The liquid of non-uniform density may have been used.
- The lead shots or steel ball may not be of small size.
- The bore in the cork may not be at the centre.
- The noted velocity may not be constant.



VIVA VOCE

- Q1. Explain Stoke's law?**
Ans. According to Stoke's law, if a small sphere of radius r is moving with a uniform velocity v through an infinite homogeneous and incompressible fluid of coefficient of viscosity η then it experiences a dragging force given by,
$$F = 6\pi\eta rv$$
This is known as Stoke's law.
- Q2. What is the reason for the steel balls to be of same radii?**
Ans. Since terminal velocity is directly proportional to the square of the radius. Therefore, the large size steel balls will fall very fast and the time of fall may not be measured accurately.
- Q3. What is the coefficient of viscosity?**
Ans. Coefficient of viscosity is numerically equal to the tangential force required to maintain a unit velocity gradient between the two layers each of unit area.
- Q4. How does the viscosity of liquid and gas change?**
Ans. Since the viscosity of a liquid decreases with increase in temperature, while that of gas increases with increase in temperature. The viscosity of liquid increases with increase in pressure whereas the viscosity of gas does not change with pressure.
- Q5. What can be the reason for the increasing radius of bubble during its upward movement?**
Ans. There is always an increase in the radius of the bubble during its upward movement because as the bubble moves up, the pressure of liquid outside decreases. So, to maintain the equilibrium with excess pressure inside it due to surface tension, the bubble expands.
- Q6. Which runs faster, cold water or a hot water?**
Ans. Hot water runs faster than a cold water because the viscosity of hot water is lesser than that of cold water.
- Q7. What kind of liquid should be used in this experiment and why?**
Ans. The clean and the transparent liquid should be used in this experiment because the motion of the boll must be visible in the liquid.
- Q8. Why do the air bubbles do not attain the terminal velocity when they move up?**
Ans. When the air bubbles move up, then their radii increase due to which the upthrust on them also increases. So, due to this reason, the air bubbles do not attain the terminal velocity during their upward movement.
- Q9. What is the effect of temperature on the coefficient of viscosity of liquid?**
Ans. The coefficient of viscosity decreases with increase in temperature because the forces of cohesion between the liquid molecules decreases with increase in temperature.
- Q10. Do all the raindrops strike the ground with the same velocity irrespective of their size?**
Ans. Since we know that the terminal velocity is directly proportional to the square of radius but as per the question, the velocity is independent of the size of raindrop. Therefore, all the raindrops strike the ground with the same velocity irrespective of their size.