Department of biology

((Biophysics))

Stage 1

LAB 4

Stock's experiment

By

M.CS Mohammad Ali Abo-Jazzra

Stock's experiment

It is a scientific experiment that aims to measure the viscosity coefficient of liquids and analyze the movement of objects through them.

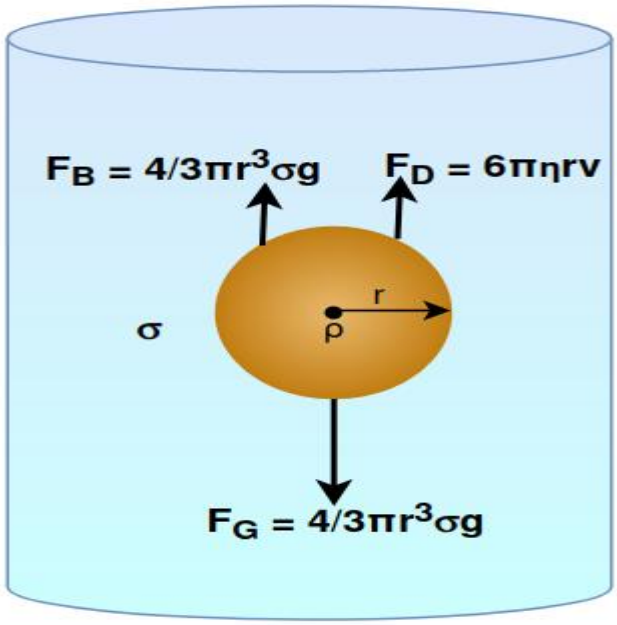
The purpose of the experiment :-

1- Determine the viscosity coefficient of a liquid.

2- Study the movement of objects in viscous fluids.

Theory:-

Stock's law is a physical law that describes the force exerted by a viscous fluid on a spherical body and is passed through it at low speed.



Derivation of Stokes' Law

Stokes' law describes the viscous drag force acting on a spherical object moving through a viscous fluid. The law can be derived by analyzing the forces acting on the object during its motion.

Assumptions of Stokes' Law:

1. **Spherical**: The moving body must be spherical.
2. **Low Velocity**: The velocity of the body must be low enough to neglect disturbances in the fluid.
3. **Viscous Fluid**: The fluid must be viscous.

Forces Acting on the Spherical Object:

When a small sphere falls through a viscous fluid, three main forces act on it:

1. **Gravitational force** (F_g) pulling the sphere downward:

   $F_g = m \cdot g \rightarrow m = p_s \cdot v \rightarrow v = 4/3 \cdot \pi \cdot r^3$

   $F_g = 4/3 \cdot \pi \cdot r^3 \cdot \rho_s \ g$

   where:

   - m is the mass of the sphere,
   - r is the radius of the sphere,
   - ρ_s (rho) is the density of the sphere,
   - g is the acceleration due to gravity.
   -

2. **Buoyant force** (F_b) exerted by the displaced fluid, according to Archimedes' principle: $F_g = m \cdot g \rightarrow m = p_f \cdot v \rightarrow v = 4/3 \cdot \pi \cdot r^3$

   $F_b = 4/3\ \pi\ r^3\ \rho_f\ g$

   Where: ρ_f (rho) is the density of the fluid.

3. **Viscous drag force (Stokes' force)** (F_u) due to the friction between the sphere and the fluid:

   $F_u = 6 \pi \eta r u$

   where:

   - f : fluid resistance force (Newtons).
   - η (Eta): skillful pair deal (Pa.s).
   - r : radius of the ball (meters).
   - v : terminal velocity of the ball (meters/second).

Terminal Velocity and Stokes' Law Derivation:

When the object reaches terminal velocity (u), the net force acting on it becomes zero, meaning the gravitational force equals the sum of the buoyant force and the viscous drag force:

$$F_g = F_b + F_u$$

$$F_u = F_g - F_b$$

$$6 \pi r \eta u = 4/3 \pi r^3 \rho_s g - 4/3 \pi r^3 \rho_f g$$

$$6 \pi r \eta u = 4/3 \pi r^3 g (\rho_s - \rho_f)$$

$$u = \frac{2r^2 g(\rho_s - \rho_f)}{9 \eta}$$

Work steps : Steps of Stokes' Experiment to Measure Viscosity

1. **Prepare the Equipment:**
   - A long glass tube filled with a viscous liquid (e.g., glycerin or oil).
   - Small spheres made of a material with a known density (e.g., glass or steel).
   - A ruler to measure distance.
   - A stopwatch to measure time.
2. **Drop the Sphere:**

   Gently release the sphere into the liquid from the top of the tube, ensuring no air bubbles are present.

3. **Measure Time and Distance:**
   - Once the sphere reaches its terminal velocity, measure the time it takes to travel between two marked points in the tube.
   - Use the ruler to measure the distance between these marks.

4. **Calculate the Terminal Velocity:**

   Compute the velocity using the formula

$$u = \frac{\textbf{distance traveled } (h)}{\textbf{time taken } (t)}$$

5. **Apply Stokes' Law:**

   Use the equation: $\eta = \frac{2r^2 g(\rho_s - \rho_f)}{9\,u}$

   to determine the viscosity of the liquid.

6. **Repeat the Experiment:**

Perform the experiment with spheres of different sizes to improve accuracy.

Q1/

A small steel ball with a radius of r=1.5 mm is dropped into a container filled with glycerin. The density of the steel ball is ρ_s= 7800 kg/m³, and the density of glycerin is ρ_f 1260 kg/m³. The viscosity of glycerin is η= 1.5 Pa.

If the ball reaches its final velocity, calculate this velocity (u) using Stokes' law?

Solution:

Using Stokes' law formula:

$$u = \frac{2r^2 g(\rho_s - \rho_f)}{9\,\eta}$$

Substituting the given values:

$$u = \frac{2(0.0015)^2 \times 9.81(7800 - 1260)}{9 \times 1.5} = 0.0214\ m/s$$

Final Answer:

The terminal velocity of the steel sphere in glycerin is **0.0214 m/s** (or **2.14 cm/s**).

Q2/

A small glass sphere with a **radius** of **2 mm** is dropped into a fluid, and it reaches a terminal velocity of **0.015 m/s**. The **density** of the sphere is **2500 kg/m³**, and the **density** of the fluid is **1000 kg/m³**.

Using **Stokes' Law**, calculate the viscosity (η\etaη) of the fluid.

Solution:

Using Stokes' law formula:

$$\eta = \frac{2r^2 g(\rho_s - \rho_f)}{9\,u}$$

Substituting the given values:

$$\eta = \frac{2(0.002)^2 \times 9.81(2500 - 1000)}{9 \times 0.015} = 0.872 \text{ pa.}s$$

Final Answer:

The viscosity of the fluid is approximately **0.872 Pa·s**.

Q1:

What is the primary purpose of Stokes' experiment?
a) To measure the density of liquids
b) To determine the viscosity coefficient of liquids
c) To calculate the gravitational force
d) To study the speed of sound in liquids

Answer: b) To determine the viscosity coefficient of liquids

Q2:

Which force is described by Stokes' law when a sphere moves through a viscous fluid?
a) Gravitational force
b) Buoyant force
c) Viscous drag force
d) Centripetal force

Answer: c) Viscous drag force

Q3:

In Stokes' law, what does the variable η represent?
a) The radius of the sphere
b) The gravitational acceleration
c) The viscosity of the fluid
d) The density of the sphere

Answer: c) The viscosity of the fluid

Q4:

What is the formula for terminal velocity in Stokes' law?
a) $u=2r^2g\,(\rho_s-\rho_f)/\,9\eta$
b) $u=r^2g\eta\,/\,9(\rho_s-\rho_f)$
c) $u=r^2g\,/\,9\eta(\rho_s-\rho_f)$
d) $u=2\eta r^3g(\rho_s-\rho_f)\,/\,9$

Answer: a)

Q5:

In Stokes' law, which of the following is required for accurate results?
a) High velocity of the sphere
b) A non-viscous fluid
c) A spherical object
d) An elliptical object

Answer: c) A spherical object

Q6:

What is the unit of viscosity in Stokes' law?
a) m/s
b) Pa·s
c) N/m^2
d) kg/m^3

Answer: b) Pa·s

Q7:

What is the role of the buoyant force in Stokes' law?
a) It determines the terminal velocity
b) It pulls the sphere downward
c) It opposes the gravitational force
d) It accelerates the sphere

Answer: c) It opposes the gravitational force

Q8:

What happens when the object reaches its terminal velocity in Stokes' law?
a) The viscous drag force becomes zero
b) The gravitational force exceeds the buoyant force
c) The net force acting on the object becomes zero
d) The velocity of the object continues to increase

Answer: c) The net force acting on the object becomes zero

Q9:

In Stokes' law, which factor affects the viscous drag force?
a) The color of the sphere
b) The radius of the sphere
c) The temperature of the fluid
d) The mass of the sphere

Answer: b) The radius of the sphere

Q10:

The viscosity of a fluid is measured in:
a) kg/m
b) m^2/s
c) Pa·s
d) $N·s/m^2$

Answer: c) Pa·s

Q11:

What happens when the density of the sphere is much larger than the density of the fluid in Stokes' law?
a) The sphere will not move
b) The velocity increases significantly
c) The viscosity becomes zero
d) The sphere reaches a high buoyant force

Answer: b) The velocity increases significantly

Q12:

Which of the following forces is NOT involved in Stokes' law?
a) Gravitational force b) Electrostatic force
c) Viscous drag force d) Buoyant force

Answer: b) Electrostatic force

Q13:

What is the effect of increasing the radius of the sphere in Stokes' law?
a) The terminal velocity decreases
b) The terminal velocity remains unchanged
c) The terminal velocity increases
d) The viscosity decreases

Answer: c) The terminal velocity increases

Q14:

Which fluid property is essential for Stokes' law to apply effectively?
a) Low temperature
b) High density
c) Viscosity
d) High compressibility

Answer: c) Viscosity

Q15:

Which of the following would cause the terminal velocity to decrease in Stokes' law?
a) Increasing the density of the sphere
b) Increasing the viscosity of the fluid
c) Increasing the radius of the sphere
d) Decreasing the gravitational acceleration

Answer: b) Increasing the viscosity of the fluid

Q16:

A small sphere with a radius of **1 mm** is dropped into a fluid. The density of the sphere is **2500 kg/m³** and the density of the fluid is **1000 kg/m³**. The viscosity of the fluid is **0.5 Pa·s**. If the terminal velocity of the sphere is **0.02 m/s**, calculate the radius of the sphere using Stokes' law.

a) 0.5 mm b) 1 mm c) 2 mm d) 3 mm

Answer: b) 1 mm

Q17:

A small steel sphere with a radius of **0.002 m** is dropped into a fluid. The density of the sphere is **7800 kg/m³** and the density of the fluid is **1200 kg/m³**. The viscosity of the fluid is **1.0 Pa·s**. If the terminal velocity of the sphere is **0.03 m/s**, calculate the terminal velocity of a sphere with radius **0.005 m** using Stokes' law.

a) 0.07 m/s b) 0.15 m/s c) 0.22 m/s d) 0.10 m/s

Answer: d) 0.10 m/s

Q18:

A sphere with a radius of **0.003 m** falls through a viscous fluid. The density of the sphere is **1500 kg/m³** and the density of the fluid is **1000 kg/m³**. The viscosity of the fluid is **0.8 Pa·s**. If the terminal velocity of the sphere is **0.04 m/s**, calculate the viscosity of the fluid if the sphere's radius is changed to **0.006 m** and the terminal velocity is **0.12 m/s**.

a) 0.6 Pa·s b) 1.2 Pa·s c) 1.5 Pa·s d) 0.8 Pa·s

Answer: b) 1.2 Pa·s

Q19:

A small glass sphere with a radius of **2 mm** is dropped into a fluid. The density of the sphere is **2500 kg/m³** and the density of the fluid is **1000 kg/m³**. The viscosity of the fluid is **1.0 Pa·s**. If the terminal velocity of the sphere is **0.01 m/s**, calculate the velocity of a sphere with radius **3 mm** falling through the same fluid.

a) 0.015 m/s b) 0.012 m/s c) 0.03 m/s d) 0.02 m/s

Answer: a) 0.015 m/s

Q20:

A small steel ball with a radius of **1.5 mm** is dropped into glycerin. The density of the steel ball is **7800 kg/m³**, and the density of glycerin is **1260 kg/m³**. The viscosity of glycerin is **1.5 Pa·s**. Calculate the terminal velocity of the ball using Stokes' law.

a) 0.01 m/s b) 0.05 m/s c) 0.0214 m/s d) 0.03 m/s

Answer: c) 0.0214 m/s

Q21:

A small glass sphere with a radius of **3 mm** is dropped into a fluid. The density of the sphere is **2000 kg/m³** and the density of the fluid is **1000 kg/m³**. The viscosity of the fluid is **0.9 Pa·s**. If the terminal velocity of the sphere is **0.02 m/s**, calculate the velocity of a sphere with radius **1.5 mm**.

a) 0.01 m/s b) 0.03 m/s c) 0.04 m/s d) 0.02 m/s

Answer: a) 0.01 m/s

Q22:

A sphere with a radius of **0.005 m** is dropped into a fluid with a viscosity of **1.2 Pa·s**. The density of the sphere is **2200 kg/m³** and the density of the fluid is **1100 kg/m³**. If the terminal velocity of the sphere is **0.05 m/s**, calculate the terminal velocity of a sphere with radius **0.002 m** falling through the same fluid.

a) 0.03 m/s b) 0.01 m/s c) 0.08 m/s d) 0.06 m/s

Answer: b) 0.01 m/s

Q23:

A steel ball is dropped into a liquid. The density of the ball is **7800 kg/m³** and the density of the liquid is **1000 kg/m³**. The viscosity of the liquid is **0.8 Pa**. If the final velocity of the ball is **0.1 m/s**, calculate the radius of the ball.

a) 0.004 m b) 0.007 m c) 0.006 m d) 0.005 m

Answer: b) 0.007 m

Q24:

A sphere with a radius of **0.002 m** is dropped into a fluid with a viscosity of **1.0 Pa·s**. The density of the sphere is **2000 kg/m³** and the density of the fluid is **1000 kg/m³**. The terminal velocity of the sphere is **0.03 m/s**. What will be the terminal velocity of a sphere with radius **0.004 m**?

a) 0.06 m/s b) 0.12 m/s c) 0.15 m/s d) 0.18 m/s

Answer: a) 0.06 m/s

Q25:

A small steel ball with a radius of **0.004 m** is dropped into glycerin. The density of the steel ball is **7800 kg/m³**, and the density of glycerin is **1260 kg/m³**. The viscosity of glycerin is **1.5 Pa·s**. Calculate the terminal velocity of the ball.

a) 0.025 m/s b) 0.015 m/s c) 0.02 m/s d) 0.03 m/s

Answer: a) 0.025 m/s
