The frictional force in fluids is due to viscosity.
If the frictional force caused by movement through the fluid is small, we say the viscosity is low.

Example: When you walk in a swimming pool, you find it much harder than walking through air. The friction acting against you is greater in water than it is in air. It would be even harder to wade through a swimming pool of oil than one full of water. This fluid dependent factor is called the coefficient of viscosity and has the symbol η, the Greek letter eta.

Dependence:
As viscosity determines the friction force acting within a fluid, it has a direct effect on the rate of flow of the fluid. The rate of flow of a fluid through a pipe is inversely proportional to the viscosity of the fluid.
►Viscosity is directly related to fluid temperature.
► In general, liquids have a lower coefficient of viscosity at higher temperatures.
►For gases, viscosity increases with temperature.
►At a fixed temperature, viscosity is constant.
►'Viscous drag' increases with velocity, but 'viscosity' does not change.

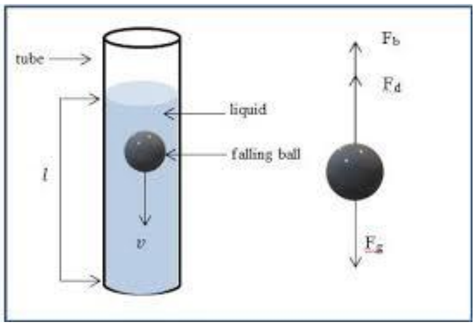
Sir George Gabriel **Stokes, an Irish mathematician and physicist at Cambridge University, investigated fluid dynamics and came up with an equation for the viscous drag (F) on a small sphere at low speeds. This formula is now called**
Stokes' law:

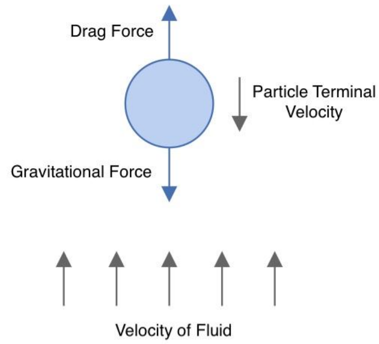
$$F = 6\pi r\eta v$$

where r is the radius of sphere (m), v is the velocity of sphere (ms^{-1}), and h is the coefficient of viscosity of the fluid (Pa s)

Que: The equation derived by dimensional analysis

small sphere at low speeds through fluid.





Terminal velocity: the velocity of a falling object when its weight is balanced by the sum of the drag and upthrust acting on it

When a body falling through a fluid drags fluids around the path through which it falls and as a result a relative motion between different layers of the fluid is created. This relative motion is resisted by viscous force. This opposite force increases with the velocity of the body and if the body is small it soon becomes equal to the force creating motion. In this state, the body falls at a constant velocity.
In equilibrium situation, the weight exactly balances the sum of upthrust and drag, which means that the falling velocity remains constant. This constant velocity is the terminal velocity

$$v_{term} = \frac{2r^2 g(\rho_s - \sigma_f)}{9\eta}$$

$$\eta = \frac{2r^2 g(\rho_s - \sigma_f)}{9v_{term}}$$

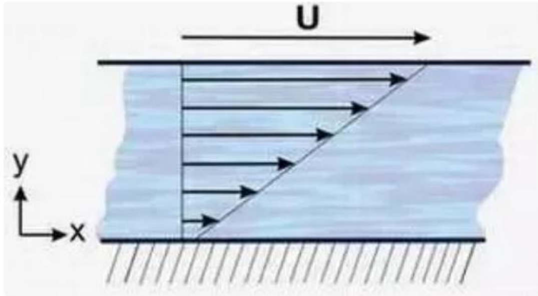
So terminal velocity is proportional to the square of the radius.

Que: Does different sized ball falls same time?

This means that a larger sphere falls faster. Furthermore, because the radius is squared, it falls much faster.
Que: Find the terminal velocity of (a) a steel ball bearing of radius 1 mm and (b) a steel ball bearing of radius 2 mm falling through glycerine in a measuring cylinder.
The viscosity of glycerin is highly temperature dependent: at 20 °C we can take η = 1.5 Pa s

Newtonian definition of viscosity for the stream line motion:

Newton's law of viscosity:



$$F = \eta A \frac{dv}{dy}$$

Co-efficient of viscosity/Dynamic viscosity

Definition: For unit velocity gradient the amount of viscous force that acts per unit are of a fluid is called co-efficient of viscosity of that fluid.

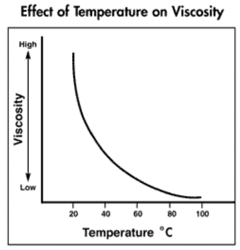
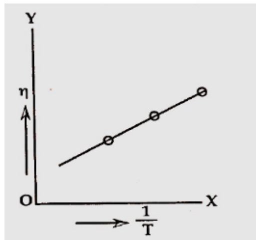
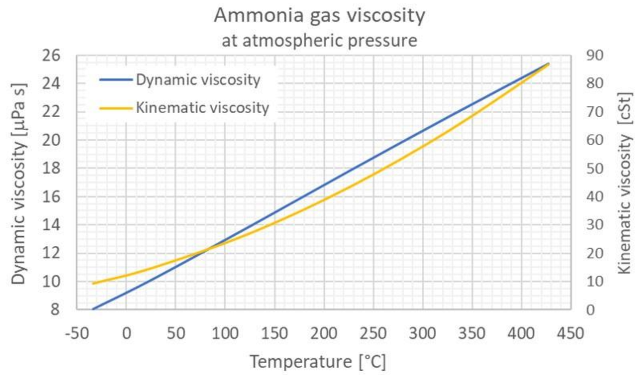
This force acts along tangent to the layers of the fluid.

or, The tangential force needed per unit area to maintain unit velocity gradient is a liquid is called coefficient of viscosity of that liquid.

Dimension and unit of co-efficient of viscosity:

$$\eta = \frac{F}{A}\frac{dy}{dv}$$

"Co-efficient of viscosity 1 Nsm^{-2}" -This statement means that 1 N tangential force is required to maintain a relative velocity of 1 ms^{-1} between two layers of a liquid having 1 m^2 area and a distance of 1m.

LIQUIDS	GASES
$$\log \eta = A + \frac{B}{T}$$	$$\eta \propto \sqrt{T}$$
 	
With the increase of temperature co-efficient of viscosity decreases. For example, the co-efficient of viscosity of water at 80°C is one third the co-efficient of viscosity at 0°C.	**In gases co efficient of viscosity increases with the increase of temperature. From experimental results it is seen that co-efficient of viscosity of gases is directly proportional to the square root of temperature**
Tangential dragging force acts between two adjacent layers of a fluid in motion. This force is called viscous force. Intermolecular force among the molecules of two layers is the cause of this viscous force. Viscous force is dependent on the interatomic distance. When temperature Increases interatomic distance also increases. As a result the interatomic force decreases; consequently viscous force decreases	Gas molecules move randomly in all directions and they collide with each other. The distance between molecules is much greater than the liquid molecules. So, intermolecular force between gas molecules is practically absent. When temperature increases average speed of molecules also increases and as a result collisions among molecules also increase. Due to the increase of collisions resistance between the flow of different layers also increases i.e., viscosity also increases.