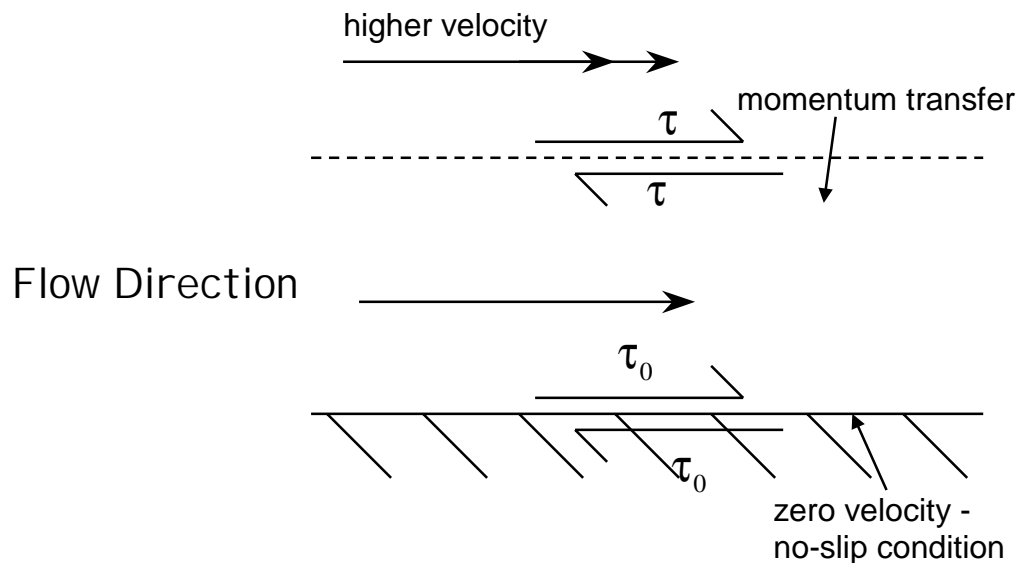


## 1.4 Viscosity

Viscosity is a measure of the effect of friction in fluid flow.

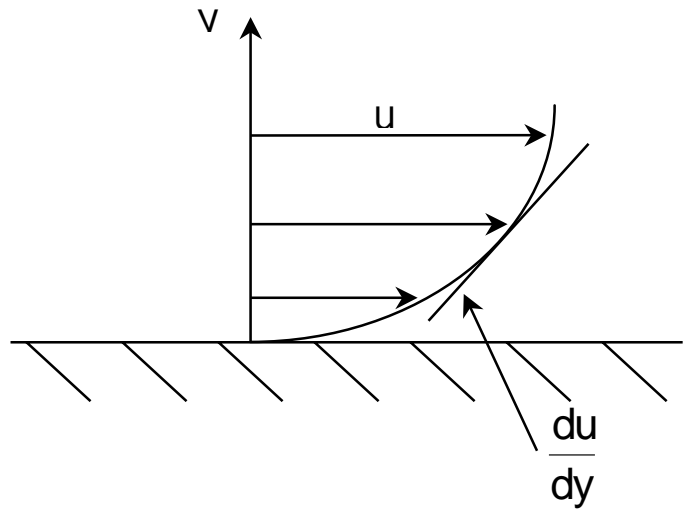
*Why does friction exist in fluid flow?*



- molecular collisions – the molecules of the fluid bump into each other, slowing down their motion
- momentum transfer from higher momentum to lower - momentum is mass times velocity,  $mu$ . During a collision, momentum will be transferred.
- measured by shear stress,  $\tau$ , which is the tangential force divided by the area

*What fluid parameters does the shear stress depend on?*

- In solids, the shear stress,  $\tau$ , is proportional to the applied force.
- In liquids, the shear stress depends on relative movement between layers of fluid.
- If the velocity is constant across the flow field, then there is no friction – often assumed to be the case away from a solid wall.
- In fluids,  $\tau$  depends on
  - the rate of change of velocity with distance across the stream
  - fluid properties



$du/dy$  is the rate of change of velocity with distance from the surface, where  $u$  is the flow velocity, and  $y$  is the distance from the plate, across the flow.

Near the surface, the rate of change of velocity is high, but further away from the plate the velocity changes more slowly, and may become constant, so  $du/dy$  gets smaller.

The shear stress is proportional to the rate of change of velocity, also called the velocity gradient. We can write this as:  $\tau \propto \frac{du}{dy}$

So near the surface, the shear stress is high, while on moving further into the stream the shear stress gets smaller.

Since  $\tau \propto \frac{du}{dy}$  we can also write  $\tau = \text{a constant} * du/dy$

The constant is called the **dynamic viscosity** of the fluid and is given the Greek symbol,  $\mu$ , 'mu'. Thus:

$$\tau = \mu \frac{du}{dy} \quad (\text{Newton's equation})$$

Viscosity is often associated with density,  $\rho$ , so a useful parameter is the **kinematic viscosity**, given the symbol  $\nu$  'nu', where

$$\nu = \frac{\mu}{\rho}$$

*What are the units of dynamic viscosity and kinematic viscosity?*

## Units of viscosity

Dynamic viscosity	$\mu$	$\text{N s m}^{-2}$ or $\text{Pa s}$ or $\text{kg m}^{-1} \text{s}^{-1}$
Kinematic viscosity	$\nu$	$\text{m}^2 \text{s}^{-1}$

Typical values of  $\mu$  at 15°C (288 K):

Air	$18 \times 10^{-6} \text{ Pa s}$
Water	$1.139 \times 10^{-3} \text{ Pa s}$
Diesel oil	$4.5 \times 10^{-3} \text{ Pa s}$
Olive oil	$106.1 \times 10^{-3} \text{ Pa s}$

Viscosity is strongly dependent on temperature: for liquids, the viscosity reduces as the temperature is raised, while for gases, the viscosity is approximately proportional to the square root of the absolute temperature, and therefore increases with temperature.

## Measurement of Viscosity

There are 3 main types of viscometer:

- measures the time taken for a fixed volume of fluid to pass through a capillary tube e.g. Redwood viscometer
- the falling sphere method, good for highly viscous fluids;
- rotary devices

Further reading:

Bacon and Stephens, Fluid Mechanics for Technicians 3/4	Chapter 6
Bacon and Stephens, Mechanical Technology	31.2
Massey, Mechanics of fluids	1.5, 6.5
White, Fluid Mechanics	1.7

**Next page:** <http://www.tech.plym.ac.uk/sme/mech225/gaslaws.pdf>

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