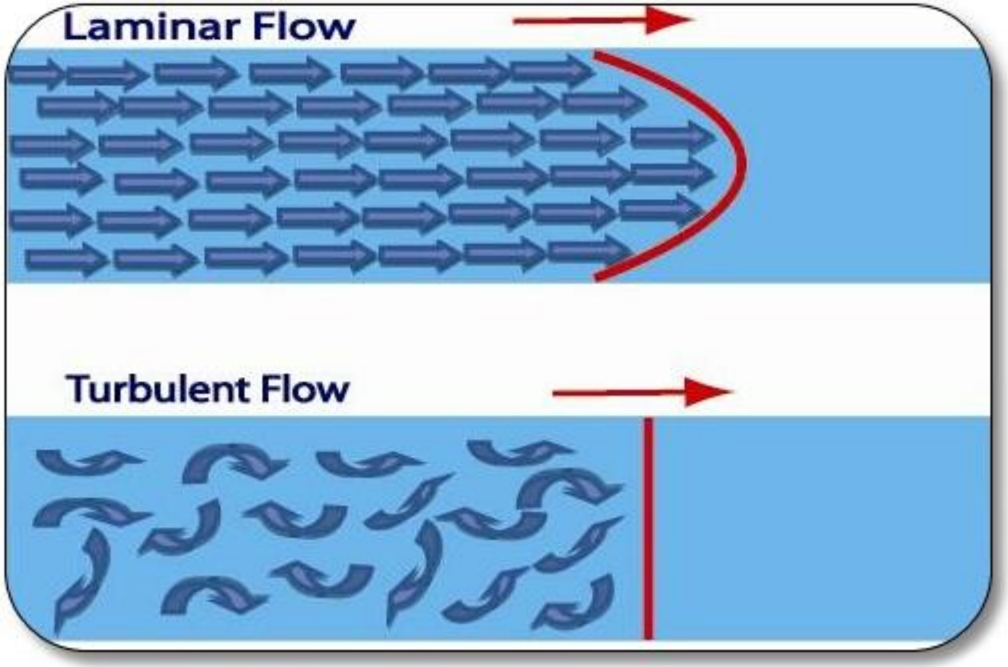
FLUID DYNAMICS

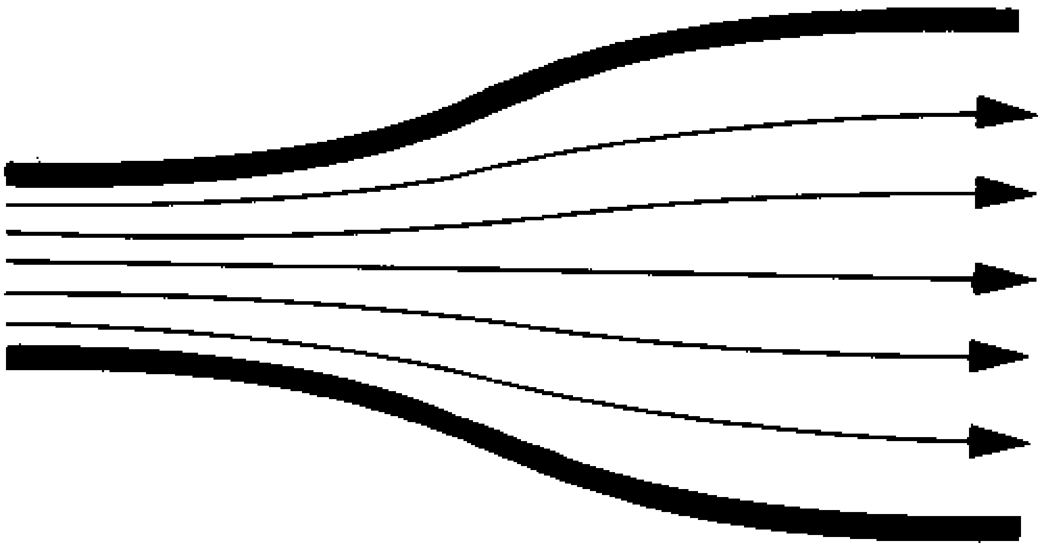
TYPES OF FLUID FLOW

- Laminar or streamline flow

- Turbulent flow

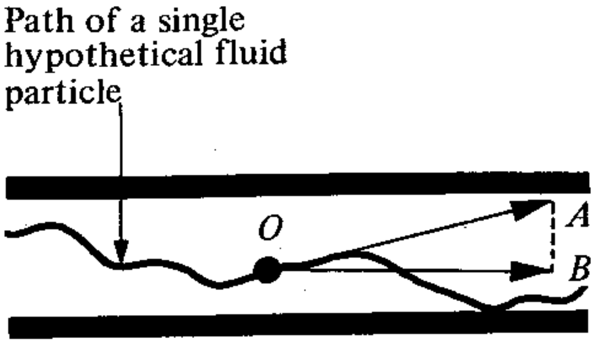


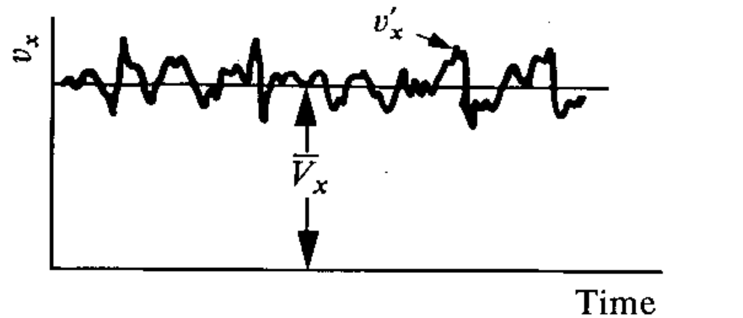
LAMINAR FLOW



Laminar or Streamline Flow, is a well-ordered flow and is characterized by the smooth sliding of adjacent fluid layers (or lamina) over one another, with mixing between layers occurring only on a molecular level.

TURBULENT FLOW





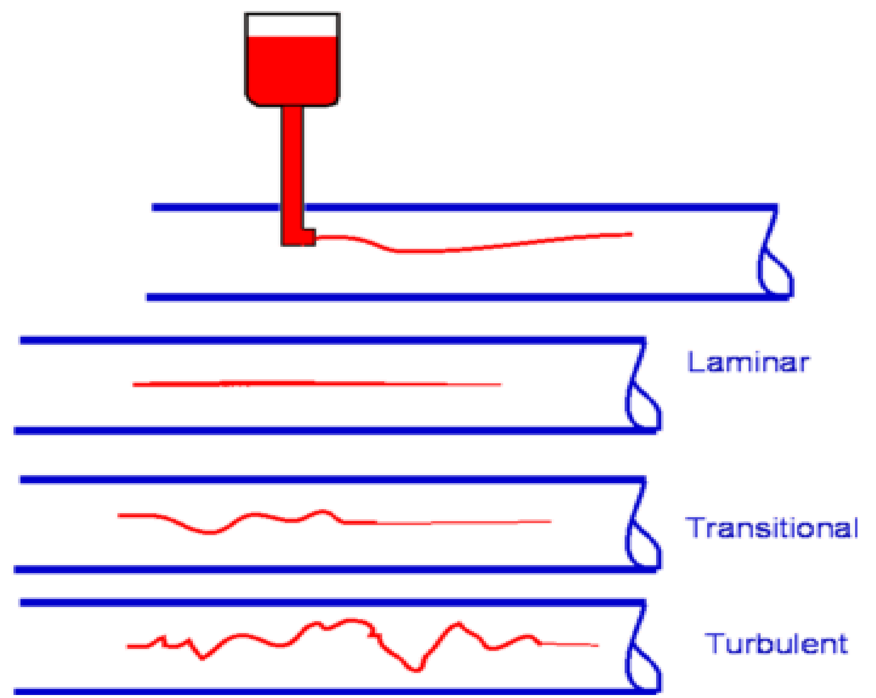
Turbulent Flow, is an erratic (irregular) flow and is characterized by the transfer of small packets of fluid particles between layers. Thus it is accompanied by fluctuations in velocity.

In turbulent flow the speed of the fluid at a point is continuously undergoing changes in both magnitude and direction.

Transition from Laminar to Turbulent Flow

When fluid flow is intensified, it tends to switch from laminar to turbulent flow.

The transition from laminar to turbulent flow was studied by Reynolds in 1883. He suggested a parameter (i.e., Reynolds number) as the criterion for predicting the type of flow in round tubes.



Reynolds Number (Re_D)

$$Re_D = \frac{D\bar{V}}{\nu} = \frac{D\rho\bar{V}}{\eta}$$

Reynolds, 1883

D = pipe diameter (m),

$\bar{V}$= the average fluid velocity (m/s),

ν = the kinematic viscosity (m^2/s),

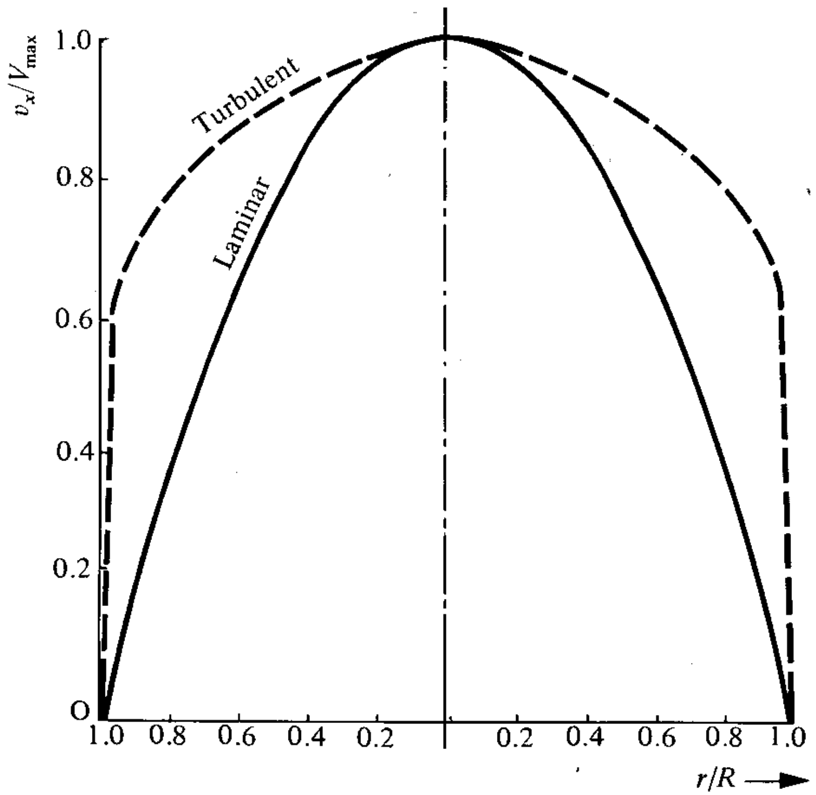
ρ= fluid density,

η = fluid or dynamic viscosity

If $Re_D < 2100$ then laminar flow
If $Re_D > 2100$ then turbulent flow

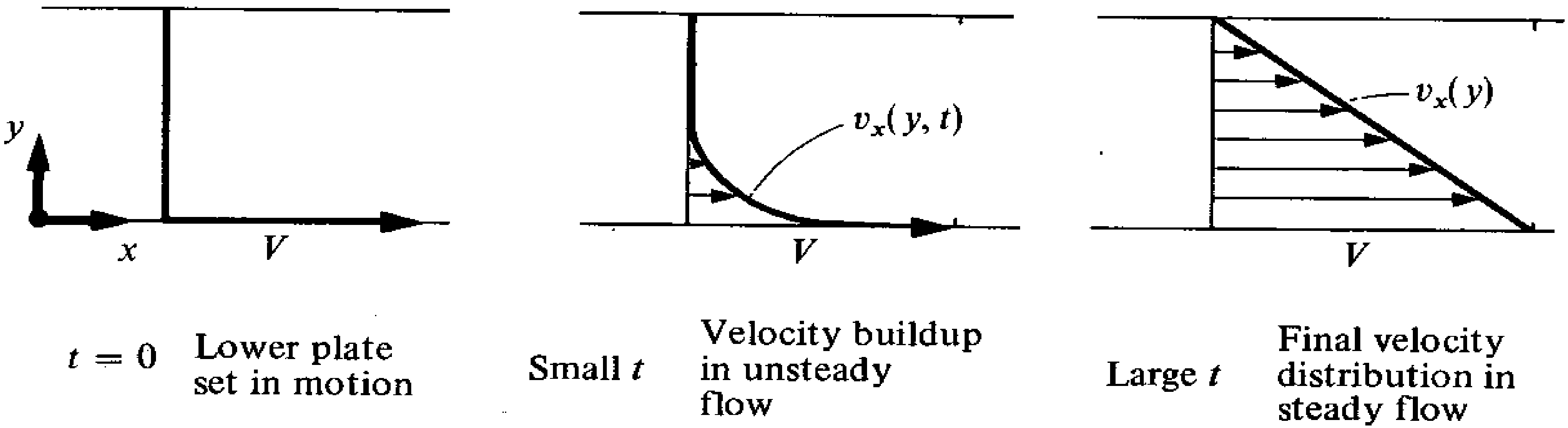
External factors such as surface roughness and initial disturbances in the fluid may change the critical Reynolds number!!!

Velocity Profiles for Laminar and Turbulent Flows



For laminar flow the velocity profile is parabolic; in turbulent flow, the curve is somewhat flattened in the middle. Notice that for both cases the velocity is zero at the fluid-wall interface, this is known as the no-slip boundary condition.

Newton's Law of Viscosity Viscosity-I



At steady state, for plates of **area A**, and laminar flow, the force is expressed by

$$F/A=\eta(V/Y)$$

where **Y is the distance** between plates and **η=constant of proportionality (viscosity)**.

Newton's Law of Viscosity Viscosity-I

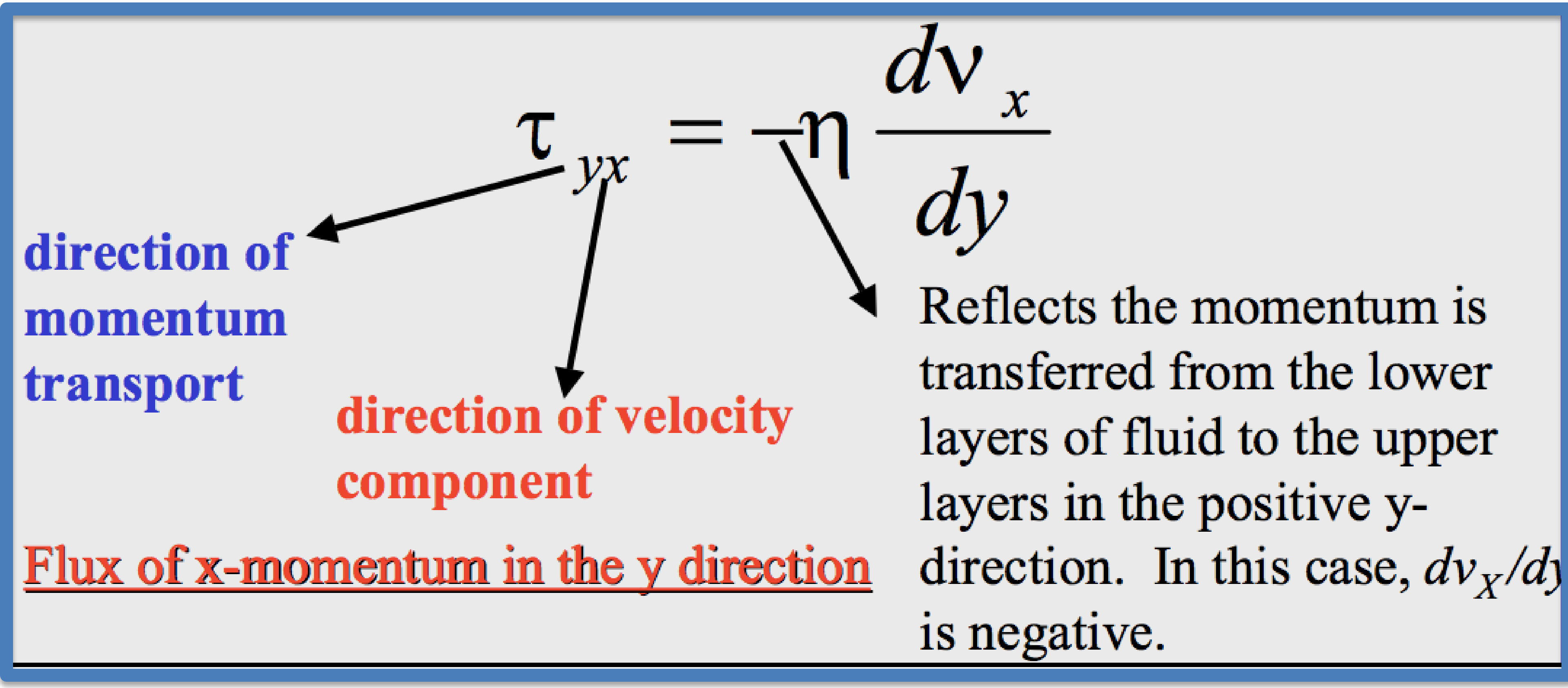
$$F/A = \eta (V/Y)$$

Shear stress

Force: Shear

Newton’s Law of Viscosity Viscosity-II

F/A = shear stress = **τ = momentum flux**
(V/Y) = the constant velocity gradient = dv_x/dy when the velocity profile is linear at steady state.



Facts about Newton’s Law of Viscosity

It is only valid in the regime of laminar flow not in the regime of turbulent flow.

Fluids that obey Newton’s law of viscosity are called **Newtonian Fluids.** All gases and simple liquids (e.g., water, molten metals, molten semiconductors, and many molten salts) are Newtonian.

On the other hand the fluids, whose viscosities depend on the rate of applied shear are called non-newtonian; clays, sullaries, pastes and polymer solutions belong to the class of non-newtonian fluids.

Fluid (or Dynamic) Viscosity (μ or η)

Dynamic viscosity is the ratio of shear stress to velocity gradient. When force is applied perpendicular to the surface of a liquid, it deforms sideways, or shears. The ease or difficulty of this deformation is the dynamic viscosity, sometimes referred to simply as viscosity.

It measures the resistance of a fluid to flow — in other words, the internal friction of the fluid

- The cgs (centimeter-gram-second) unit of stress is dyn.cm^{-2} or g.cm^{-1}.s^{-2}. Therefore, the cgs unit of **viscosity is g/cm.s = Poise (P)**

1 Centipoise (cP) = the viscosity of water at 20°C and 1 atm.

1cP = 0.01 P

- In mks system, the corresponding unit of viscosity is Pa.s (N.s/m^2) or kg.m .s , and is equivalent to 10^3 cP (or 10 P)

Kinematic Viscosity (υ)

Kinematic viscosity, measures the resistance of the liquid to flow in the presence of gravity. This measure is obtained by taking the liquid’s dynamic viscosity and dividing it by the liquid’s density. The higher the viscosity of the liquid, the less easily it will flow under the force of gravity and the higher its kinematic viscosity will be.

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

- In **mks** system, the **unit of kinematic viscosity is m^2/s** , while in the **cgs** system it is usually **cm^2/s** , sometimes called the **stoke**.

Dynamic and Kinematic Viscosity

Dynamic and kinematic viscosity are expressed in different units of measurement.

The International System of Units (SI) measurement units for dynamic viscosity :pascal-seconds or poise (another measure relating pressure versus time)

The common unit used to measure kinematic viscosity is the stokes, or square centimeters per second, although sometimes the SI unit of square meters per second is used.