Kinematics Fluid

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Fluid Kinematics

What is fluid kinematics?

- Fluid kinematics is the study on fluid motion in space and time without considering the force which causes the fluid motion.

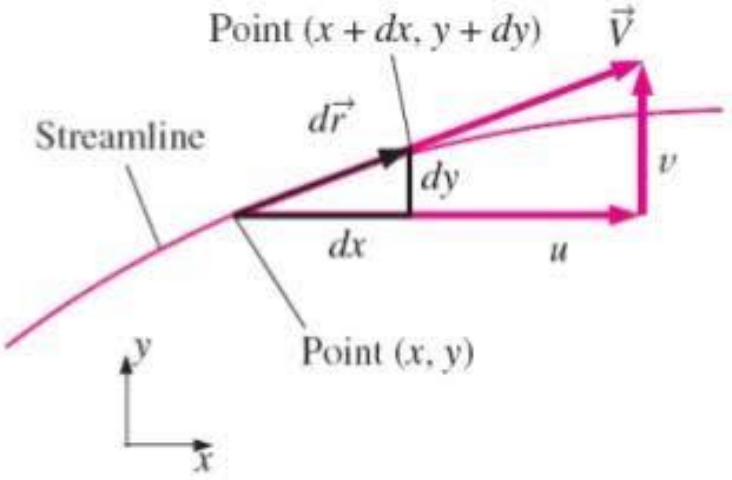
- According to the continuum hypothesis the local velocity of fluid is the velocity of an infinitesimally small fluid particle/element at a given instant t. It is generally a continuous function in space and time.

Streamlines and Streamtubes

Streamline: A curve that is everywhere tangent to the instantaneous local velocity vector.

Stream line at any instant can be defined as an imaginary curve or line in the flow field, so that the tangent to the curve at any point, represents the direction of the instantaneous velocity at that point.

Streamlines are useful as indicators of the instantaneous direction of fluid motion throughout the flow field.

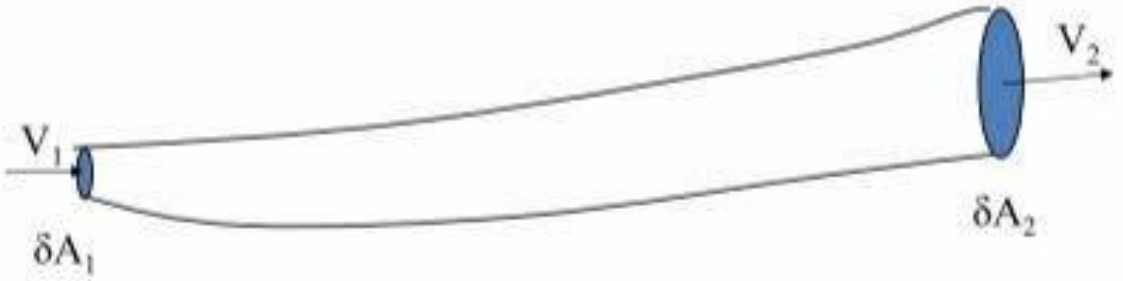


For two-dimensional flow in the xy-plane, arc length $d\vec{r} = (dx, dy)$ along a *streamline* is everywhere tangent to the local instantaneous velocity vector $\vec{V} = (u, v)$.

Stream Tube

A region of the moving fluid bounded on the all sides by streamlines is called a tube of flow or stream tube.

As streamline does not intersect each other, no fluid enters or leaves across the sides.



When density do not depend explicitly on time then from continuity equation, we have

$$\nabla \cdot (\vec{v}\rho) = 0$$

Bernoulli's Principle

Theory - Equation

$$P_1 + \frac{1}{2}\rho V_1^{\,2} + \rho g h_1 = P_2 + \frac{1}{2}\rho V_2^{\,2} + \rho g h_2$$

Where (in SI units)

P= static pressure of fluid at the cross section
ρ= density of the flowing fluid
g= acceleration due to gravity;
v= mean velocity of fluid flow at the cross section
h= elevation head of the center of the cross section with respect to a datum.

- **Bernoulli's Principle states that the sum of pressure energy per unit volume, kinetic energy per unit volume and potential energy per unit volume of an incompressible, non-viscous fluid in a streamlined irrotational flow remains constant along a streamline.** Mathematically,

$$p + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$$

$$\Leftrightarrow p_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

What do you mean by Renault number?

The Reynolds number is the ratio of inertial forces to viscous forces. The Reynolds number is a dimensionless number used to categorize the fluids systems in which the effect of viscosity is important in controlling the velocities or the flow pattern of a fluid.

$$\mathrm{Re} = \frac{\rho v l}{\mu} = \frac{v l}{\nu}$$

Where:

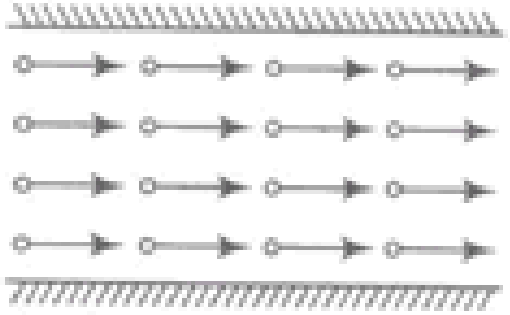
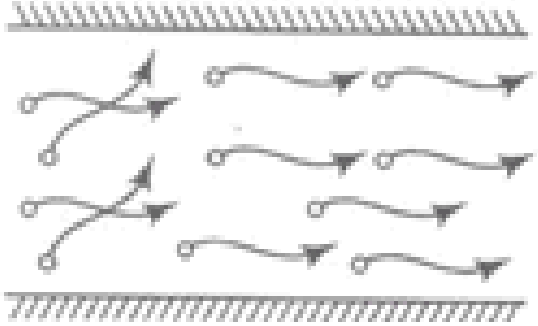
v = Velocity of the fluid

l = The characteritics length, the chord width of an airfoil

ρ = The density of the fluid

μ = The dynamic viscosity of the fluid

ν = The kinematic viscosity of the fluid

Laminar Flow	Turbulent Flow
The flow in which the adjacent layers do not cross each other and move along well defined path. 	The flow in which adjacent layers cross each other and do not move along well defined path. 

Coefficient of Viscosity

Assume a fluid between two solid surfaces

A force is required to move the upper surface

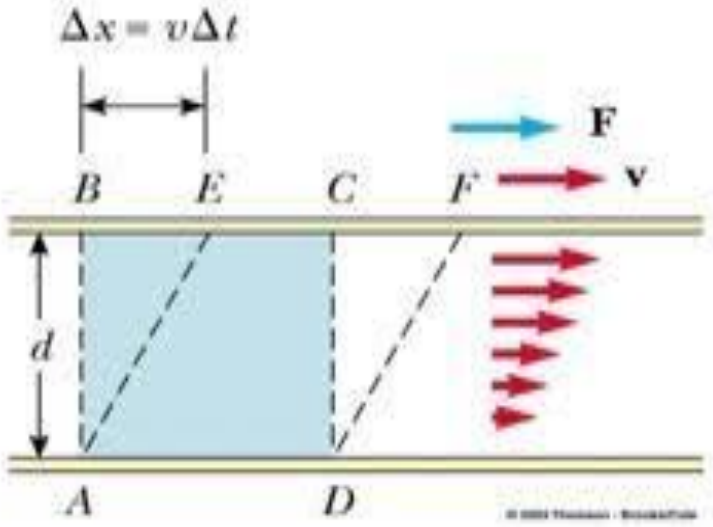
$$F = \eta \frac{Av}{d}$$

η is the coefficient

SI units are Ns/m^2

cgs units are Poise

1 Poise = 0.1 Ns/m^2



Examples Viscosity

- Motor oil, in the winter, flowing from its container flows slow, but in the summer it flows fast.
- Pancake syrup, just out of the refrigerator, flowing from the bottle flows slow, but when warmed up by placing it under warm water will flow fast.

** *relate to the particle theory*.


Thank You