

# Summary | Fluid Dynamics

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## Introduction

### Flow

Motion with relative movement between fluid particles where continuous deformation happens.

### Classification of fluid flow

#### Density

##### Incompressible

Density doesn't vary significantly.

Examples:

- Pipe and channel flows of liquids
- Gas flows in pipes

$$\frac{|\Delta\rho|}{\rho} \ll 1$$

##### Compressible

Density varies significantly.

Examples:

- Pressure surges in pipes

#### Viscosity

##### Non-viscous

Fluid doesn't show any resistance to the flow.

## Viscous

Fluid shows any resistance to the flow.

- **Newtonian:**  $\mu$  is constant  
Examples: Water
- **Non-newtonian:**  $\mu$  is not constant  
Examples: Paints, Clay, Plastics

## Variation of parameters

The parameters:

- Velocity  $V$
- Pressure  $P$
- Flow rate  $Q$

## Temporal Variation

The variation of the parameters with time.

- **Steady:** no variation with time  
 $V = f(x, y, z)$
- **Unsteady:** variation of flow parameters with time  
 $V = f(t, x, y, z)$

## Spatial Variation

The variation of the parameters with coordinates.

- **Uniform:** no variation with spatial parameters  
 $V = f(t)$
- **Non-uniform:** spatial variation of flow parameters  
 $V = f(t, x, y, z)$

## Dimensional

If a variation of flow parameter in a certain direction can be neglected, that can reduce the calculations.

## Nature of movement

- **Laminar**: Fluid particles move in a orderly fashion
- **Turbulent**: Fluid particles move disorderly

## Rotation of particles

- **Rotational**: Usually due to shear forces. Flow of real fluids.
- **Non-rotational**: Flow of frictionless forces.

## Flow patterns

### Streamline

A line tangential to the flow velocity.

### Streamtube

A passage enclosed by a collection of streamlines.

### Pathline

Path traced by an individual fluid particle.

### Streakline

Suppose a dye is injected into a fluid flow. Streakline indicates the positions of all particles passed through the point of injection.

#### Note

In steady flow: streamline, pathline and streakline all coincide.

## Conservation Laws

In fluid dynamics, 4 laws are used to analyse the fluid flow.

- Laws of mechanics
- Conservation of mass
- Conservation of energy
- Conservation of momentum

These laws are applied to a specific volume of the fluid in motion, and it's called as control volume.

## Control volume

A volume, through which a fluid flows.

- It's a fixed volume
- Can either be real or imaginary

## Conservation of mass

Mass cannot be created nor destroyed.

## Conservation of energy

Energy cannot be created nor destroyed, but can be converted from one form to another.

## Conservation of momentum

Unless a resultant force is exerted on a mass, it cannot gain or lose momentum.

## Momentum

$$M = \text{mass} \times \text{velocity} = mv$$

## Derivations

### Continuity equation

From the conservation of mass law, the below equation can be derived for an incompressible fluid:

$$Q = Av$$

Here:

- $Q$  - Flow rate
- $A$  - Cross-sectional area
- $v$  - velocity

### Bernoulli's equation

For an incompressible fluid in steady flow, total head on a point is constant throughout a [streamline](#).

Can be derived from the conservation of energy law.

$$\text{Total head } H = z + \frac{P}{\rho g} + \frac{v^2}{2g}$$

Here:

- $z$  - Datum head. Height to the point from a reference level.
- $\frac{P}{\rho g}$  - [Pressure head](#).
- $\frac{v^2}{2g}$  - Velocity head. Kinetic energy per unit weight.

#### Note

- Head is the energy per unit weight.
- Piezometric head is equal to  $\frac{P^*}{\rho g}$  where  $P^*$  is the piezometric pressure.

### Steady flow momentum equation

$$F_S = \dot{M}_o - \dot{M}_i$$

Here:

- $F_S$  - Force exerted on the fluid within the control volume
- $\dot{M}_o$  - Rate of change of momentum of the inflow fluid
- $\dot{M}_i$  - Rate of change of momentum of the outflow fluid

