# Chapter 1 INTRODUCTION AND BASIC CONCEPTS

## 1. Fluids and no-slip condition

* Fluid: a substance that deforms continuously when subjected to shear stresses
* No-slip condition: no relative motion between fluid and boundary

## 2. Basic units

|  |  |  |  |
| --- | --- | --- | --- |
|  | Dimension | SI unit | BG unit |
| Velocity  |  |  |  |
| Acceleration  |  |  |  |
| Force  |  |  () |  |
| Pressure  |  |  () |  |
| Density  |  |  |  |
| Internal energy  |  |  () |  |

## 3. Weight and mass

* W (N) = , where = 9.81 m/s2
* W (lbf) = , where = 32.2 ft/s2
* 1 N = 1 Kg × 1 m/s2
* 1 lbf = 1 slug × 1 ft/s2
* 1 slug = 32.2 lbm (weighs 32.2 lb under standard gravity)

## 4. Properties involving mass or weight of fluid

* Specific weight = (N/m3)
* Specific gravity =

## 5. Viscosity

* Newtonian fluid:
	+ Shear stress (N/m2; lb/ft2)
	+ Coefficient of viscosity (Ns/m2; lb⋅s/ft2)
	+ = Kinematic viscosity (m2/s; ft2/s)
* Non-Newtonian fluid:

Ex) Couette flow

 ,

## 6. Vapor pressure and cavitation

* When the pressure of a liquid falls below the vapor pressure it evaporates, i.e., changes to a gas.
* If the pressure drop is due to fluid velocity, the process is called cavitation.
* Cavitation number
* implies cavitation

## 7. Surface tension

* Surface tension force
* = line force with direction normal to the cut
* = surface tension [N/m]
* = length of cut through the interface

# Chapter 2 PRESSURE AND FLUID STATICS

## 1. Absolute pressure, Gage pressure, and Vacuum



* , = gage pressure
* , = vacuum pressure

## 2. Pressure variation with elevation

* For a static fluid, pressure varies only with elevation and is constant in horizontal , planes.



* If the density of fluid is constant,
	+ = constant (piezometric pressure)
	+ = constant (piezometric head)
	+ gage, : increase linearly with depth, decrease linearly with height

## 3. Pressure measurements (Manometry)

### 1) U-tube manometer

*
* gage

### 2) Differential U-tube manometer

*
*
* + If fluid is a gas :
	+ If fluid is liquid & pipe horizontal :

## 4. Hydrostatic forces on plane surfaces

### 1) Horizontal surfaces



*
* Line of action is through centroid of , i.e.,

### 2) Inclined surfaces



* + : pressure at centeroid of
	+ : 1st moment of area
* Magnitude of resultant hydrostatic force on plane surface is product of pressure at centeroid of area and area of surface
* Center of pressure

 : moment of inertia with respect to horizontal centeroidal axis

For plane surfaces with symmetry about an axis normal to 0-0, and

## 5. Hydrostatic forces on curved surfaces



* ( : projection of onto plane to -direction)
* ( : projection of onto plane to -direction)
* = weight of fluid above surface

## 6. Buoyancy

* 
* Fluid weight equivalent to body volume
* Line of action is through centeroid of = center of buoyancy

## 7. Stability

### 1) Immersed bodies



* Static equilibrium requires: and .
* requires and the body is neutrally stable
* If is above : stable (righting moment when heeled)
* If is above : unstable (heeling moment when heeled)

### 2) Floating bodies

* The center of buoyancy generally shifts when the body is rotated
* Metacenter M: The point of intersection of the lines of action of the buoyant force before and after heel



* + GM: metacentric height
	+ = moment of inertia of waterplane area about centerplane axis
* GM > 0: stable (M is above G)
* GM < 0: unstable (G is above M)

## 8. Fluids in rigid-body motion

* If no relative motion between fluid particles
* For rigid body translation:
	+
	+ ⇒
		- = unit vector in direction normal of
* For rigid body rotation:
	+ -
	+ or ()
	+ : curves of constant pressure ( : pressure at (r,z)=(0,0))

# Chapter 3 BERNOULLI EQUATION

## 1. Flow patterns

* Stream line: a line that is everywhere tangent to the velocity vector at a given instant
* Pathline: the actual path traveled by a given fluid particle
* Streakline: the locus of particles which have earlier passed through a particular point

## 2. Streamline coordinates

* Velocity :
* Acceleration:
	+ = local in direction
	+ = local in direction
	+ = convective due to spatial gradient of
	+ = convective due to curvature : centrifugal acceleration
	+ : the radius of curvature of the streamline

## 3. Bernoulli equation

* Euler equation:
* Along streamline

or

* Across streamline
* Assumptions
	+ Inviscid flow
	+ Steady flow
	+ Incompressible flow
	+ Flow along a streamline

## Fig5-54. Applications of Bernoulli equation

### 1) Stagnation tube

, , ,

### 2) Pitot tube

* ****
	+ = piezometric head
*

 from manometer or pressure gage

### 3) Simplified continuity equation

* Volume flow rate:
* Mass flow rate:
* Conservation of mass:
* For incompressible flow (=constant): or

### 4) Flow rate measurement

* If the flow is horizontal (, steady, inviscid, and incompressible,
* If velocity profiles are uniform at sections (1) and (2),
* Flow rate is,

Ex) Venturi meter



# Chapter 4 FLUIDS KINEMATICS

## 1. Velocity and description Methods

* Lagrangian: keep track of individual fluids particles
* Eulerian: focus attention on a fixed point in space

## 2. Acceleration and material derivatives

* Lagrangian:
* Eulerian:

where,

* = local or temporal acceleration. Velocity changes with respect to time at a given point.
* = convective acceleration. Spatial gradients of velocity
* Material (substantial) derivative

## 3. Flow classification

* One-, Two-, and Three-dimensional flow
* Steady vs. Unsteady flow
* Incompressible and Compressible flow
* Viscous and Inciscid flow
* Rotational vs. Irrotational flow
* Laminar vs. Trubulent viscous flow
* Internal vs. External flow
* Separated vs. Unseparated flow

## 4. Reynolds Transport Theorem (RTT)

Special Cases:

* Non-deforming CV moving at constant velocity:
* Fixed CV:
* Steady flow:
* Uniform flow across discrete CS (steady or unsteady):

## 5. Continuity equation

Simplifications:

* Steady flow:
* = constant over discrete (flow sections):
* Incompressible fluid ( = constant): (conservation of volume)
* Steady One-dimensional flow in a conduit: , , for = const