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Fluid Mechanics

Introduction to Fluid Mechanics

by
Dr. Nor Azlina binti Alias
Faculty of Civil and Earth Resources Engineering
azlina@ump.edu.my

Chapter Description

- Aims
  - Describe Fluid Properties and the fundamentals of Fluid Mechanics concept.

- Expected Outcomes
  - Define fluid mechanics
  - Describe Fluid Properties and the fundamentals of Fluid Mechanics concept.

- References

  - Douglas F.J., Gasiorek J.M., Swaffield J.A. Fluid Mechanics. Prentice Hall 4th Edition.
  - Bruce R. M., Donald F.Y and Theodore H.O. Fundamentals of Fluid Mechanics. Wiley.
  - Nakayama Y and Broucher R.F. Introduction to Fluid Mechanics. Revised. Butterworth Heinmann.

Topic : **Introduction to Fluid Mechanics**

- Subtopic 1.1
  - **What is Fluid?**
- Subtopic 1.2
  - **Dimensions and Units**
- Subtopic 1.3
  - **Other Common Units used in Fluid**
- Subtopic 1.4
  - **Fluid Properties**

Introduction

- Fluids essential to life
  - Human body 95 % water
  - Earth surface 2/3 water
- History shaped by fluid mechanics
  - Geomorphology (physical features of the earth's surface and their relation to its geological structures).
  - Human migration and civilization (evolution from ship to aero plane)
  - Modern scientific and mathematical theories and methods
  - Warfare (military equipment etc)

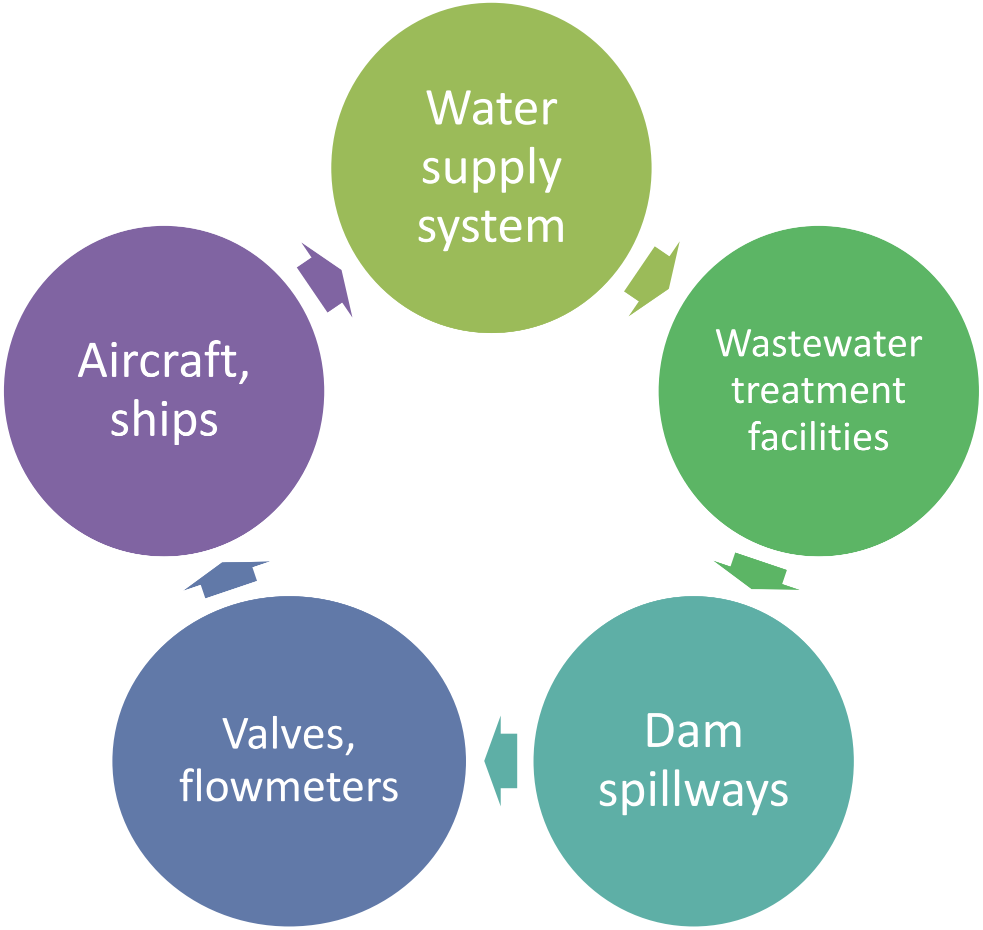
Application of Fluid Mechanics

- Storage and distribution of water, blood flow in veins are some examples of fluid flow.

- Some of the many aspects of our lives involve Fluid Mechanics are:
  - Weather & climate
  - Vehicles: automobiles, trains, ships, and planes, etc.
  - Environment
  - Physiology and medicine
  - Sports & recreation
  - Many other examples!

Fluid Engineering

- A knowledge of Fluid Mechanics is required to properly design:-



1.1 What is Fluid Mechanics

- Fluid Mechanics

A branch of applied mechanics concerned with the statics and dynamics of fluids; liquids and gases.

Analysis of the fluid's behavior is based on the fundamental laws of mechanics which relate continuity of mass and energy with force and momentum together with the familiar solid mechanics properties.

A science that deals with the action of forces and fluid.

Three states of matter that normally recognize : solid, liquid and gas.

A substance which can flow, thus distinguishes it from a solid.

1.1 what is Fluid Mechanics

- Fluids may be divided into liquid and gases.
- Fluid condition can be divided into 2:
  - Fluid at rest (called as fluid static)
  - Fluid in motion (fluid kinematics and fluid dynamic)
- Fluid statics : forces acting on fluid are due to pressure and gravity only
- Fluid kinematics : deals with velocities and streamlines without considering forces or energy
- Fluid dynamics : concerned with the relations between velocities and accelerations and the forces exerted by or upon fluids in motion (inertia forces and other forces associated with fluid in motion).
- Fundamental principles such as conservation of mass, energy and Newton's law of motion are needed to analyze problems in fluid mechanics.

Fluid Mechanics

Solid mechanics

- Shape constant
- Volume constant
- Mass constant

Fluid statics

- Shape changes
- Volume constant
- Mass constant

Fluid dynamics

- Area changes
- Volume constant
- Mass constant

Fluid

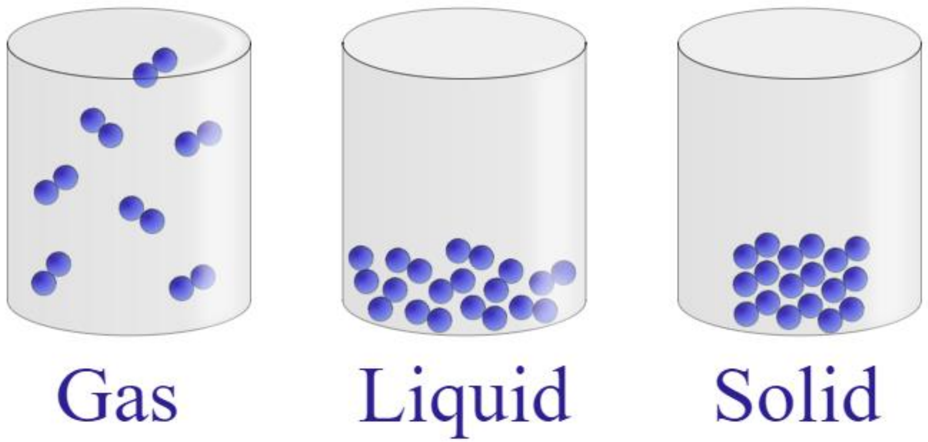
- In contrast to solids,
  - fluid lacks in resist deformation. (It cannot resist the deformation force)
  - moves and flows under the action of the force.
  - flows under its own weight.
  - its shape will change continuously as long as the force is applied.
  - Fluid will deform continuously under shearing stresses, no matter how small the stress.

- While a solid can resist a deformation force while at rest, this force may cause some displacement (unable to retain any unsupported shape)

- Liquid & gas cannot resist any shear stress and deforms continuously under the influence of such forces.

Fluid Mechanics :

- Solids have definite shape and volume, liquids have definite volume and assume the shape of the container, gases expand to fill and take volume and shape of the container.



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- Fluid is a substance which deforms continuously for as long as the force

Liquids and gases

- Although liquids and gasses behave in much the same way and share many similar characteristics, they also possess distinct characteristics of their own. There are differences between liquid and gas as listed in table below:

Liquids	Gases
• Difficult to compress • Fixed volume • Irrespective of the size/shape of its container • Free surface is formed if the volume of container is greater than that liquid	• Easy to compress • Change volume with pressure/temperature • Completely fill any vessel in which it is place • Does not form a free surface

1.2 Dimension and Units

- There are different ways used to express the various quantities involved in fluid mechanics. It is essential that all quantities are expressed in the same unit thus, to avoid any confusion, a SI or metric system is used.
- The metric system consists of six primary units as listed in below.

Quantity	SI Unit	Dimension
length	Metre,m	L
mass	Kilogram,kg	M
time	Second,s	T
Temperature	Kelvin,K	θ
Current*	Ampere,A	I
Luminosity*	Candela	Cd

1.3 Other Common Units Used In Fluid Mechanics – applications

- Units of measurement for many quantities derived from the basic units. It is important to evaluate the solution with correct and standard units.

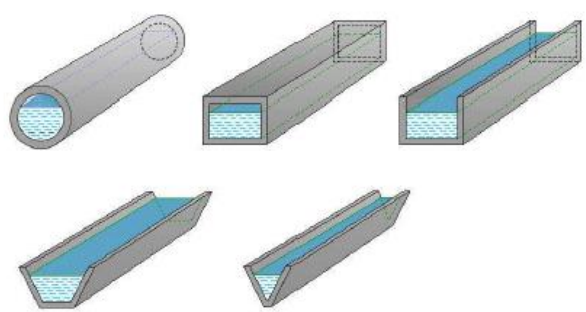
▪ Area, *A* (m^2)	$A = \text{width} \times \text{length}$
▪ Volume, *V* (m^3) ▪ Depend on the shape of an object. ▪ $1m^3$ = 1000 L	$V = \text{breadth} \times \text{length} \times \text{depth}$
▪ Velocity, v (m/s) ▪ The rate of change of displacement. It measures the pace of a moving object.	$\text{Average velocity, v} = \dfrac{\text{displacement (length)}}{\text{time taken}}$
▪ Acceleration, *a* (m/s^{-2}) ▪ The rate of increase in velocity.	$\text{Average acceleration, a} = \dfrac{\text{increase in velocity}}{\text{time taken}}$

Other Common Units Used In Fluid Mechanics

- Force, *F* (N or kgm/s^{-2})
  - The magnitude of force is given in Newton unit. Calculated using the following equation: →
  - Force normally exerts on a body.   1N = 1 kgm/s^{-2}

$$F = m \bullet a$$

- Flowrate or discharge, *Q* (m^3/s)
  - The rate of fluid flows and defined as:→
  - Since liquid and gases flow through pipes, the volume of flow rate will depend on the size or cross-section of the pipe (*A*) and the average velocity (v).



$$Q = \frac{\text{Volume of fluid detained}}{\text{time taken}}$$

$$Q = \frac{\text{Cross-sectional area} \times \text{L}}{\text{t}}$$

- Thus substituting gives : →

$$Q = Av$$

1.3 Other Common Units Used In Fluid Mechanics

Quantity	Dimensions	Imperial Unit	SI Units
Acceleration, a	LT^{-2}	$ft.s^{-2}$	$m.s^{-2}$
Area, a	L^2	ft^2	m^2
Density, ρ	ML^{-3}	$slug.ft^{-3}$	$kg.m^{-3}$
Volumetric Flow rate, Q	L^3T^{-1}	$ft^3.s^{-1}$	$m^3.s^{-1}$
Kinematic viscosity, v	L^2T^{-1}	$ft^2.s^{-1}$	$m^2.s^{-1}$
Power, P	FLT^{-1}	$Ib.ft.s^{-1}$	$N.m.s^{-1}$
Pressure, p	FL^{-2}	$Ib.in^{-2}$	$N.m^{-2}$
Specific weight, g	FL^{-3}	$Ib.ft^{-3}$	$N.m^{-3}$
Velocity, v	LT^{-1}	$ft.s^{-1}$	$m.s^{-1}$
Volume, V	L^3	ft^3	m^3

Other dimensions and units commonly used