

**Module 1**

**Chapter 1 : Basic Concepts : Fluid Properties**

1-1 to 1-21

**Basic Concepts** : Significance of fluid mechanics, physical properties of fluid, Newton’s law of viscosity, Newtonian and non-Newtonian Fluid.

**1.1 Introduction..... 1-1**

**1.2 Development and Significance of Fluid Mechanics..... 1-2**

**1.3 Fluid Continuum ..... 1-2**

**1.4 Units of Measurements..... 1-3**

1.4.1 SI Units (System International d’units)..... 1-3

1.4.2 Conversion Factors ..... 1-4

**1.5 Mass Density ( $\rho$ )..... 1-5**

**1.6 Specific Weight ( $\gamma$ )..... 1-5**

**1.7 Specific Volume ( $v$ ) ..... 1-5**

**1.8 Specific Gravity ( $s$ ) ..... 1-5**

**1.9 Viscosity ..... 1-6**

1.9.1 Newton’s Law of Viscosity..... 1-6

1.9.2 Definition of viscosity and its Variation with Pressure and Temperature ..... 1-7

1.9.3 Units and Dimensions of Dynamic and Kinematic Viscosities ..... 1-8

1.9.4 Newtonian & Non- Newtonian Fluids (Rheological Definitions of Fluids)..... 1-8

**1.10 Vapour Pressure ..... 1-9**

1.10.1 Cavitation..... 1-9

**1.11 Compressibility and Elasticity ..... 1-10**

**1.12 Surface Tension and Capillarity ..... 1-11**

1.12.1 Surface Tension ( $\sigma$ )..... 1-11

1.12.2 Capillarity ..... 1-12

**1.13 Solved Examples ..... 1-14**

**Chapter 2 : Fluid Statics**

2-1 to 2-38

**Fluid Statics** : Pascal’s law, hydrostatic law, hydrostatic force on submerged surfaces (vertical, inclined & curved). Archimedes principle, buoyancy.

**2.1 Fluid Pressure ..... 2-1**

2.1.1 Static Fluid Pressure at a point..... 2-1

2.1.2 Pressure variation in Incompressible Fluid (Hydrostatics law)..... 2-1

2.1.3 Pascal’ Law..... 2-2

2.1.4 Atmospheric, Absolute, Gauge and Vacuum Pressure ..... 2-3

2.1.5 Solved Examples..... 2-3

**2.2 Hydrostatic Pressure Force on Plane and Curved Surfaces..... 2-4**

2.2.1 Horizontal Plane Surfaces..... 2-4

2.2.2 Inclined and Vertical Plane Surface ..... 2-5

2.2.3 Moment of Inertia & Geometric Properties of Plane Surfaces ..... 2-7

2.2.4 Pressure Diagram ..... 2-8

2.2.5 Curved Surfaces..... 2-8

2.2.6 Solved Examples : Examples on Pressure forces on Plane Surfaces..... 2-10

**2.3 Buoyancy and Floatation..... 2-26**

2.3.1 Buoyant Force (Archimedes’s Principle) and Floatation..... 2-26

2.3.2 Metacentre and Metacentric Height ..... 2-27

2.3.3 Stability of Submerged and Floating Bodies..... 2-28

2.3.4 Solved Examples..... 2-29

**Module 2**

**Chapter 3 : Fluid Kinematics 3-1 to 3-23**

**Fluid Kinematics :** Classification of fluid flow, streamline, path line, streak line, acceleration of fluid particle, differential equation of continuity, rotational flow and vortices, stream function, potential function, concept of circulation.

3.1 **Methods of Describing Fluid Motion** ..... 3-1

3.2 **Velocity of Fluid Particle**..... 3-1

3.3 **Classification of Fluid Flow** ..... 3-2

3.3.1 Steady and Unsteady Flow ..... 3-2

3.3.2 Uniform & Non-uniform Flow..... 3-2

3.3.3 One, Two, Three-dimensional Flow ..... 3-2

3.3.4 Rotational & Irrotational Flow ..... 3-3

3.3.5 Laminar & Turbulent Flow ..... 3-3

3.3.6 Compressible and Incompressible Fluid Flow..... 3-4

3.3.7 Critical, Sub Critical and Supercritical Flows ..... 3-4

3.4 **Description of Flow Pattern**..... 3-4

3.4.1 Stream line ..... 3-4

3.4.2 Stream Tube ..... 3-4

3.4.3 Path Line..... 3-4

3.4.4 Streak line..... 3-5

3.5 **Acceleration of a Fluid Particle** ..... 3-5

3.5.1 Acceleration in Three Dimensional Flow ..... 3-5

3.5.2 Acceleration in One Dimensional Flow ..... 3-5

3.6 **Basic Principles of Fluid Flow**..... 3-6

3.7 **Concept of Control Volume** ..... 3-6

3.8 **Continuity Equation**..... 3-6

3.8.1 Differential Equation of Continuity ..... 3-7

3.8.2 Introduction to Continuity Equation for One Dimensional Flow ..... 3-8

3.9 **Rotational & Irrotational Motions**..... 3-8

3.10 **Circulation ( $\Gamma$ ) & Vorticity ( $\vec{\xi}$ )** ..... 3-9

3.11 **Velocity Potential OR Potential Function**..... 3-9

3.12 **Stream Function**..... 3-10

3.13 **Introduction to Streamlines, Equipotential Lines and Flow net** ..... 3-11

3.14 **Solved Examples** ..... 3-11

**Module 3**

**Chapter 4 : Fluid Dynamics 4-1 to 4-31**

**Fluid Dynamics :** Concept of control volume and control surface, Importance of Reynolds Transport theorem (RTT) and its derivation (No numerical). Forces acting on fluid in motion, Euler's equation in Cartesian coordinates, Expression of Bernoulli's equation from principle of energy conservation and by integration of Euler's equation. Application of Bernoulli's equation in Orifice meter, Venturi meter, Rotameter and Pitot tube. Momentum of fluid in motion: impulse momentum relationship and its applications for determination of thrust for pipe bend.

4.1 **Introduction** ..... 4-1

4.2 **Concept of system, control volume and control surface**..... 4-1

4.3 **Importance of Reynolds Transport Theorem (RTT) and its derivation** ..... 4-2

4.3.1 Importance of Reynolds Transport Theorem ..... 4-2

4.3.2 Volume and Mass Flow Rates ..... 4-2

4.4 **Forces Acting on Fluid in Motion and various Equations of Motion** ..... 4-3

4.5 **Euler's Equation of Motion for Three Dimensional Flow (in Cartesian Coordinates)** 4-4

4.6 **Integration of Euler's Equation to obtain Bernoulli's Equation** ..... 4-5

4.7 **Significance of each term of Bernoulli's Equation and Assumptions**..... 4-6

**4.8 Bernoulli's Equation from principle of energy conservation..... 4-8**

**4.9 Kinetic Energy Correction Factor ..... 4-8**

**4.10 Fluid Power ..... 4-9**

**4.11 Applications of Bernoulli's Equation ..... 4-9**

4.11.1 Venturimeter..... 4-9

4.11.2 Orifice Meter.....4-12

4.11.3 Pitot Tube .....4-12

4.11.4 Rotameter.....4-14

**4.12 Momentum of fluid in motion : Impulse momentum relationship..... 4-14**

4.12.1 Impulse momentum relationship.....4-14

**4.13 Applications of Momentum Equation: Thrust for Pipe Bend..... 4-15**

**4.14 Force on Pipe Bend ..... 4-15**

**4.15 Solved Examples ..... 4-16**

**Module 4**

**Chapter 5 : Laminar Viscous Flow 5-1 to 5-18**

**Laminar Viscous Flow** : Introduction to Reynolds number, critical Reynolds number, Navier-Stokes equation of motion, Relationship between shear stress and pressure gradient in laminar flow, Laminar flow between parallel plates (Plane Poiseuille & Couette flow), Laminar flow in circular pipe (Hagen-Poiseuille flow).

**5.1 Introduction and Relationship Between Shear Stress and Pressure Gradient in Laminar Flow 5-1**

**5.2 Introduction to Reynolds Number and Critical Reynolds Number ..... 5-2**

**5.3 Navier-Stokes Equation of Motion ..... 5-2**

**5.4 Steady and Uniform Laminar Flow in Circular Pipe (Hagen-Poiseuille Equation) ..... 5-4**

**5.5 Steady & Uniform Laminar Flow Between Parallel Plates (Plane Poiseuille and Couette Flow ..... 5-7**

**5.6 Solved Examples ..... 5-10**

**Module 5**

**Chapter 6 : Flow Through Pipes 6-1 to 6-22**

**Flow Through Pipes** : Reynolds experiment, Head loss in pipes due to friction (Darcy-Weisbach equation), Loss of energy in pipe (major and minor), Hydraulic gradient and Energy gradient line, Pipes in series and parallel, concept of equivalent pipe.

**6.1 Introduction ..... 6-1**

**6.2 Reynolds Experiment ..... 6-1**

**6.3 Energy losses through pipes ..... 6-2**

6.3.1 Major Energy Loss (Frictional Loss,  $h_f$ ) .....6-2

6.3.2 Minor Energy Losses.....6-3

**6.4 Concept of Equivalent Length of a minor loss .. 6-6**

**6.5 Hydraulic Gradient and Energy gradient line .. 6-6**

**6.6 Pipes in Series ..... 6-7**

**6.7 Pipes in Parallel ..... 6-7**

**6.8 Equivalent Pipes - compounding of Pipes..... 6-7**

**6.9 Flow Through Long Pipe (between Two Reservoirs and from a Single Reservoir) ..... 6-8**

**6.10 Pipeline with a Pump or Turbine..... 6-9**

**6.11 Solved Examples ..... 6-9**

**Module 6**

**Chapter 7 : Hydrodynamic Boundary Layer Theory and Flow Around Submerged Objects 7-1 to 7-23**

**Hydrodynamic Boundary Layer Theory** : Concept of formation of boundary layer, boundary layer parameters, boundary layer along a long thin plate and in pipe, Prandtl boundary layer equation, Separation of boundary layer and its methods of control.

**Flow around submerged objects** : Concept of drag and lift, Types of drag, Streamlined and bluff bodies, Drag and lift on an aerofoil.

<b>7.1</b>	<b>Boundary Layer Theory</b> .....	<b>7-1</b>
7.1.1	Introduction.....	7-1
7.1.2	Concept of Formation of Boundary Layer .....	7-1
7.1.3	Thicknesses of Boundary Layer.....	7-2
7.1.3.1	Nominal Thickness ( $\delta$ ) .....	7-2
7.1.3.2	Displacement Thickness ( $\delta^*$ ) .....	7-3
7.1.3.3	Momentum Thickness ( $\theta$ ).....	7-3
7.1.3.4	Energy Thickness ( $\delta_E$ ).....	7-4
7.1.4	Boundary Layer along a long, thin, Smooth Flat Plate and its characteristics .....	7-4
7.1.5	Boundary Layer in Pipe .....	7-6
7.1.6	Prandtl Boundary Layer Equations.....	7-7
7.1.7	Separation of Boundary Layer.....	7-7
7.1.8	Methods of Controlling Separation .....	7-9
7.1.9	Solved Examples.....	7-10
<b>7.2</b>	<b>Flow around Submerged Objects</b> .....	<b>7-16</b>
7.2.1	Concept of Drag and Lift.....	7-16
7.2.2	Types of Drag and Streamlined and Bluff bodies.....	7-17
7.2.3	Expressions for Drag & Lift and Drag & Lift Coefficients .....	7-19

7.2.4	Drag and Lift on Airfoil and Polar Diagram .....	7-19
7.2.5	Solved Examples.....	7-21

**Module 2**

**Chapter 8 : Dimensional Analysis 8-1 to 8-4**

**Dimensional Analysis** : Introduction to dimensional analysis of thermal and fluid systems, Methods of dimensional analysis - Buckingham  $\pi$  Theorem and Rayleigh's Method (Only derivations, no numerical)

<b>8.1</b>	<b>Introduction and Applications of Dimensional Analysis</b> .....	<b>8-1</b>
8.1.1	Applications of Dimensional Analysis .....	8-1
<b>8.2</b>	<b>System of Dimensions</b> .....	<b>8-1</b>
<b>8.3</b>	<b>Dimensional Homogeneity (Fourier's principle)</b> .....	<b>8-1</b>
<b>8.4</b>	<b>Methods of Dimensional Analysis</b> .....	<b>8-2</b>
8.4.1	Rayleigh's Method.....	8-2
8.4.2	Buckingham Pi ( $\pi$ ) Theorem .....	8-2
8.4.2.1	Procedure of Buckingham Pi ( $\pi$ ) theorem .....	8-3
8.4.2.2	Superfluous & Omitted Variables and limitation of Dimensional Analysis.....	8-3
<b>8.5</b>	<b>Introduction to Model Investigations</b> .....	<b>8-4</b>

