MATH-491 Fluid Mechanics

Credit Hours: 3-0

Pre-requisite: None

Course Objectives: Fluid mechanics deals with the fluids in a static or in a dynamic state. Most of the phenomena occurring in human lives are mostly fall in this subject. Either we study the flow of air around an aeroplane or study the air flow around a vehicle on the road we must understand the laws of fluid mechanics. The key topics in this subject includes real and ideal fluids, steady and unsteady flows, velocity potential, Bernoulli's equations, incompressible fluid, streamlines, streaklines and pathlines, Reynold transport theorem, Navier-Stokes equations, potential flows, boundary layer equations, vorticity and rotation, viscous stresses and rotation, dimensional analysis.

Core Contents: Introduction, Pressure Distribution in a Fluid, Integral Relations for a Control Volume, Differential Relations for a Fluid Particle, Dimensional Analysis and Similarity

Detailed Contents:

Preliminary Remarks: Introduction.

The Concept of a Fluid: The Concept of a Fluid

The Fluid as a Continuum: The Fluid as a Continuum

Dimension and Units: Primary Dimension, Consistent Units

Properties of the Velocity Field: Eulerian and Lagrangian Description,The Velocity Field Thermodynamic Properties of a Fluid: Pressure, Temperature, Density, Specific Weight, Specific Gravity, Potential and Kinetic Energies, State Relations for Gases, State Relations for Liquids

Viscosity and Other Secondary Properties: Viscosity, The Reynolds Number, Flow Between Plates, Variation of Viscosity with Temperature, Thermal Conductivity, Non-Newtonian Fluids, Vapor Pressure, No Slip and No Temperature Jump Conditions, Speed of Sound

Basic Flow Analysis Techniques: Basic Flows Analysis Technique

Flow P atterns: Streamlines, Streaklines an d Pathlines: Flow Patterns: Streamlines, Streaklines a ndPathlines

Pressure and Pressure Gradient: Pressure Force on a Fluid Element

Equilibrium of a Fluid Element: Equilibrium of a Fluid Element, Gage Pressure and Vacuum Pressure:Relative Terms

Hydrostatic Pressure Distribution: Hydrostatic Pressure Distribution, Hydrostatic Pressure in Liquid, Hydrostatic Pressure in Gases

Pressure Measurement: Pressure Measurement

Basic Physical Laws of Fluid Mechanics: Basic Physical Laws of Fluid Mechanics, System versus Control Volume, Volume and Mass Rate of Flow

The Reynolds Transport Theorem: The Reynolds Transport Theorem, One Dimensional Fixed Control Volume, Arbitrary Fixed Control Volume

Conservation of Mass: Conservation of Mass, Incompressible Flow

The Linear Momentum Equation: The Linear Momentum Equation, One Dimensional Momentum Flux, Net Pressure on a Closed Control Surface

The Angular Momentum Theorem: The Angular Momentum Theorem

The Energy Equation: The Energy Equation, One Dimensional Energy F lux T erm, The Steady F low Energy Equation,

Frictionless Flow: The Bernoulli Equation: Frictionless Flow: The Bernoulli Equation, Relation Between the Bernoulli and Steady Flow Energy Equations

The Acceleration Field of a Fluid: The Acceleration Field of a Fluid

The Differential Equation of Mass Conservation: The Differential Equation of Mass Conservation, Cylindrical Polar Coordinates, Steady Compressible Flow, Incompressible Flow

The Differential Equation of Linear Momentum: The Differential Equation of Linear Momentum, Inviscid Flow: Euler Equation, Newtonian Fluid: Navier-Stokes Equations

The Differential Equation of Energy: The Differential Equation of Energy

Boundary Conditions for the Basic Equations: Boundary Conditions for the Basic Equation, Simplified Free Surface Conditions, Incompressible Flow with Constant Properties, Inviscid Flow, Approximation.

The Stream Function: The Stream Function, Geometric Interpretation of ψ, Steady Plane Compressible Flows, Incompressible Plane Flow in Polar Coordinates, Incompressible Axisymmetric Flows

Vorticity and Irrotationality: Vorticity and Irrotationality

Frictionless Irrotational Flows: Frictionless Irrotational Flows, Velocity Potential, Orthogonality of Streamlines and Potential Lines, Generation of Rotationality

Some Illustrative Incompressible Viscous Flows: Couette Flow between a Fixed and a Moving Plate, Flow Due to Pressure Gradient between Two Fixed Plates

Introduction: Introduction

The Principle of Dimensional Homogeneity: The Principle of Dimensional Homogeneity, Ambiguity: The Choice of Variables and Scaling Parameters, Some Peculiar Engineering Equation

Learning Outcome: On successful completion of this course, students will be able to:

understand the governing laws for fluid flows which will be helpful in understanding physicalphenomena.

model and solve the fluid flow problems.

differentiate between different types of flows e.g. steady or unsteady flows etc.

Textbook:

Frank M. White , Fluid Mechanics, 8th Edition, McGraw-Hill Higher Education, 2017.

Recommended Books

1. Fluid Mechanics: Fundamentals and Applications by Yunus A Çengel and John M Cimbala, 3rdEdition, McGraw-Hill Science/Engineering/Math, 2013.
2. Fluid Mechanics by Pijush K. Kundu and Ira M. Cohen and David. R. Dowling, 5th Edition,Academic Press , 2011.

Weekly Breakdown		
Week	***Section***	**Topics**
1	1.1-1.3	**Preliminary Remarks:** Introduction **The Concept of a Fluid:** The Concept of a Fluid **The Fluid as a Continuum:** The Fluid as a Continuum
2	1.4-1.6	**Dimension and Units:** Primary Dimension, Consistent Units **Properties of the Velocity Field**: Eulerian and Lagrangian Description,The VelocityField **Thermodynamic Properties of a Fluid:** Pressure, Temperature, Density, Specific Weight, Specific Gravity, Potential and Kinetic Energies, State Relations for Gases, State Relations for Liquids
3	1.7	**Viscosity and Other Secondary Properties:** Viscosity, The Reynolds Number, FlowBetween Plates, Variation of Viscosity with Temperature, Thermal Conductivity, Non-Newtonian Fluids, VaporPressure, No Slip and No Temperature Jump Conditions, Speed of Sound
4	1.8-1.9	**Basic Flow Analysis Techniques:** Basic Flows Analysis Technique **Flow Patterns: Streamlines, Streaklines and Pathlines:** Flow Patterns: Streamlines,Streaklines and Pathlines
5	2.1-2.2	**Pressure and Pressure Gradient:** Pressure Force on a Fluid Element **Equilibrium of a Fluid Element:** Equilibrium of a Fluid Element, Gage Pressure andVacuum Pressure: Relative Terms
6	2.3	**Hydrostatic Pressure Distribution:** Hydrostatic Pressure Distribution, HydrostaticPressure in Liquid, Hydrostatic Pressure in Gases
7	3.1	**Basic Physical Laws of Fluid Mechanics:** Basic Physical Laws of Fluid Mechanics,System versus Control Volume, Volume and Mass Rate of Flow

8	3.2-3.4	**The Reynolds Transport Theorem:** The Reynolds Transport Theorem, One Dimensional Fixed Control Volume, Arbitrary Fixed Control Volume **Conservation of Mass:** Conservation of Mass, Incompressible Flow **The Linear Momentum Equation:** The Linear Momentum Equation, One Dimensional Momentum Flux, Net Pressure on a Closed Control Surface
9	**Midterm**	
10	3.5, 3.7	**Frictionless Flow: The Bernoulli Equation:** Frictionless Flow: The Bernoulli Equation**,** Relation Between the Bernoulli and Steady Flow Energy Equations **The Energy Equation:** The Energy Equation, One Dimensional Energy Flux Term, The Steady Flow Energy Equation,
11	4.1-4.3	**The Acceleration Field of a Fluid**: The Acceleration Field of a Fluid **The Differential Equation of Mass Conservation:** The Differential Equation of Mass Conservation, Cylindrical Polar Coordinates, Steady Compressible Flow, Incompressible Flow **The Differential Equation of Linear Momentum:** The Differential Equation of Linear Momentum, Inviscid Flow: Euler Equation, Newtonian Fluid: Navier-Stokes Equation
12	4.5 4.6	**The Differential Equation of Energy:** The Differential Equation of Energy **Boundary Conditions for the Basic Equations:** Boundary Conditions for the Basic Equation, Simplified Free Surface Conditions, Incompressible Flow with Constant Properties, Inviscid Flow Approximation
13	4.7-4.8	**The Stream Function:** The Stream Function, Geometric Interpretation of $\psi\psi$, Steady Plane Compressible Flows, Incompressible Plane Flow in Polar Coordinates, Incompressible Axisymmetric Flows **Vorticity and Irrotationality:** Vorticity and Irrotationality
14	4.9	**Frictionless Irrotational Flows:** Frictionless Irrotational Flows, Velocity Potential, Orthogonality of Streamlines and Potential Lines, Generation of Rotationality
15	4.10	**Some Illustrative Incompressible Viscous Flows:** Couette Flow between a Fixed and a Moving Plate, Flow Due to Pressure Gradient between Two Fixed Plates
16	5.1-5.2	**Inroduction**: Introduction **The Principle of Dimensional Homogeneity**: The Principle of Dimensional Homogeneity, Ambiguity: The Choice of Variables and Scaling Parameters, Some Peculiar Engineering Equation
17	**5.3**	**The Pi Theorem**
18		**End semester Exam**