Indian Institute of Engineering Science and Technology, Shibpur

Proposed Course Structure for Two-Year M. Tech Program
(From 2019 Onward)

Department of Aerospace Engineering and Applied Mechanics

M. Tech in Applied Mechanics:
(Specializations: Mechanics of Solids; Mechanics of Fluids)

A. First Semester

Sl. No	Paper	Credit
1	Paper-I (Dep. Core)	3
2	Paper-II (Dep. Core)	3
3	Paper-III (Dep. Core)	3
4	Paper-IV (Dep. Elec/ Open Elec.)	3
5	Paper-V (Dep. Elec/ Open Elec.)	3
	Theory Subtotal	**15**
6	Lab - I/ Mini Project - I	2
7	Lab - II/Mini Project - II	2
8	Lab - III/Mini Project - III	2
	Practical Subtotal	**6**
	Total Credit	**21**

Note:

1. Paper – I, II and III are compulsory subjects for the particular specialization.

2. Paper – IV, V are elective subjects, which are to be selected from the table below. A student may also opt for open electives offered by other departments for first semester M. Tech Students (subject to availability).

3. Lab – I, II, III are typically related to Paper – I, II and III. However, in some cases, if the Department feels, these may be related to Paper – IV and V also (for departmental electives only). In cases, where lab facility is not available, mini projects related to Paper – I/II/III may be offered.

4. The credits mentioned above are indicative and are as such to be followed. However, in cases, where it is essential to include a Tutorial or to increase the lab hours, credits may be increased to 4 (Theory)/3(Practical). In such cases, the total credit should not exceed 24.

Indian Institute of Engineering Science and Technology, Shibpur

Proposed Course Structure for Two-Year M. Tech Program
(From 2019 Onward)

Table - 1

Specialization: **Mechanics of Solids (MOS)**

a) Departmental Core Papers for the specialization (Paper – I, II, III)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	**AM5101**	Theory of Elasticity	3	0	0	3	3	100
2	**AM5102**	Theory of Vibration	3	0	0	3	3	100
3	**AM5103**	Finite Element Method in Solid Mechanics	3	0	0	3	3	100

b) Departmental Elective(**DE**) Papers for the specialization (Paper – IV, V)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	**AM5121**	Continuum Mechanics	3	0	0	3	3	100
2	**AM5122**	Mechanics of Composite Materials	3	0	0	3	3	100
3	**AM5123**	Biomechanics	3	0	0	3	3	100

c) Departmental Labs for the specialization (Lab – I, II)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	**AM5171**	Programming in Solid Mechanics	0	0	2	2	2	100
2	**AM5172**	Software Aided Simulation in Solid Mechanics	0	0	2	2	2	100

d) Departmental Mini Projects for the specialization (Mini Project-I)

Sl. No	Subject code	Related Paper Code and Name	Total load (h)	Credit	Marks
1	**AM5173**	-	2	2	100

Indian Institute of Engineering Science and Technology, Shibpur

Proposed Course Structure for Two-Year M. Tech Program
(From 2019 Onward)

Specialization: **Mechanics of Fluids (MOF)**

a) Departmental Core Papers for the specialization (Paper – I, II, III)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	**AM5106**	Viscous Fluid Flow	3	0	0	3	3	100
2	**AM5107**	Convective Heat Transfer	3	0	0	3	3	100
3	**AM5108**	Methods in Computational Fluid Dynamics	3	0	0	3	3	100

b) Departmental Elective (**DE**) Papers for the specialization (Paper – IV, V)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	**AM5121**	Continuum Mechanics	3	0	0	3	3	100
2	**AM5126**	Turbomachineries	3	0	0	3	3	100
3	**AM5127**	Theory of Hydraulic Models	3	0	0	3	3	100
4	**AM5128**	Water Wave Mechanics and Coastal Processes	3	0	0	3	3	100
5	**AM5129**	Computational Aerodynamics	3	0	0	3	3	100

c) Departmental Labs for the specialization (Lab – I, II)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	**AM5176**	Programming in Fluid Dynamics	0	0	2	2	2	100
2	**AM5177**	Experiments and Simulation in Fluid Dynamics	0	0	2	2	2	100

d) Departmental Mini Projects for the specialization (Mini Project-I)

Sl. No	Subject code	Related Paper Code and Name	Total load (h)	Credit	Marks
3	**AM5178**	-	2	2	100

e) Open Elective (**OE**) Courses (Paper – IV,V)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	**AM5161**	Mechatronics	3	0	0	3	3	100
2	**AM5162**	Human Body Mechanics	3	0	0	3	3	100

B. Second Semester

Sl. No	Paper	Credit
1	Paper - VI (Dep. Core)	3
2	Paper - VII (Dep. Core)	3
3	Paper - VIII (Dep. Core)	3
4	Paper-IX (Dep. Elec/ Open Elec.)	3
5	Paper-X (Dep. Elec/ Open Elec.)	3
	Theory Subtotal	**15**
6	M. Tech Project Part - I (Term Paper)	4
7	Term Paper Seminar & Viva-voce	2
8	**Practical Subtotal**	**6**
	Total Credit	**21**

Note:

1. Paper – VI, VII and VIII are compulsory subjects for the particular specialization.
2. Paper – IX, X are elective subjects, which are to be selected from the table below. A student may also opt for open electives offered by other departments for second semester M. Tech Students (subject to availability).
3. For M. Tech Thesis Part - I (Term Paper), the student will work under the guidance of the Supervisor(s) from the beginning of the second semester, and submit the Term Paper (literature review and objective and scope of the broad area of M. Tech thesis work). Submission will be followed by a seminar and Viva-voce.
4. The credits mentioned above are indicative and are as such to be followed. However, in cases, where it is essential to include a Tutorial credits may be increased to 4 (Theory). In such cases, the total credit should not exceed 23.

Table - 2
Specialization: **Mechanics of Solids (MOS)**
a) Departmental Core Papers for the specialization (Paper – VI, VII, VIII)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	**AM5201**	Theory of Plasticity	3	0	0	3	3	100
2	**AM5202**	Theory of Elastic Stability	3	0	0	3	3	100
3	**AM5203**	Mechanics of Plates and Shells	3	0	0	3	3	100

b) Departmental Elective (**DE**) Papers for the specialization (Paper- IX, X)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	**AM5232**	Engineering Optimization	3	0	0	3	3	100
2	**AM5234**	Engineering Fracture Mechanics	3	0	0	3	3	100
3	**AM5236**	Nonlinear Dynamics and Chaos	3	0	0	3	3	100
4	**AM5238**	Stochastic Structural Dynamics	3	0	0	3	3	100
5	**AM5240**	Micromechanics of Composites	3	0	0	3	3	100
6	**AM5242**	Advanced Finite Element Method in Solid Mechanics	3	0	0	3	3	100

Specialization: **Mechanics of Fluids (MOF)**
a) Departmental Core Papers for the specialization (Paper – VI, VII, VIII)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	**AM5215**	Fluid Power Control System	3	0	0	3	3	100
2	**AM5216**	Theory of Turbulence	3	0	0	3	3	100
3	**AM5217**	Compressible Flow	3	0	0	3	3	100

b) Departmental Elective (**DE**) Papers for the specialization (Paper- IX, X)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	**AM5232**	Engineering Optimization	3	0	0	3	3	100
2	**AM5236**	NonlinearDynamics and Chaos	3	0	0	3	3	100
3	**AM5244**	Parallel Computation in CFD	3	0	0	3	3	100
4	**AM5246**	Instrumentation in Fluid Mechanics	3	0	0	3	3	100
5	**AM5248**	Microfluidics	3	0	0	3	3	100

c) M. Tech Project Part - I

Sl. No	Subject code	Subject Name	Total load (h)	Credit	Marks
1	**AM5291**	M. Tech thesis Part - I (Term Paper)	8	4	200
2	**AM5292**	Term Paper Seminar & Viva-voce		2	100

d) Open Elective (**OE**) Courses (Paper – IX, X)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	**AM5263**	Free Surface Flow	3	0	0	3	3	100
2	**AM5264**	Parallel Computation for Engineers	3	0	0	3	3	100

Third Semester

Sl. No	Paper	Credit
1	M. Tech Thesis Part - II (Progress Report)	12
2	Progress Report Seminar & Viva-voce	6
	Total Credit	**18**

Note:

1. For M. Tech Thesis Part - II (Progress Report), the student will submit the details of work done for the M. tech Thesis during the third semester, and findings (if any). Submission will be followed by a seminar and Viva-voce.

M. Tech Project Part - II

Sl. No	Subject code	Subject Name	Total load (h)	Credit	Marks
1	**AM6191**	M. Tech Thesis Part - II (Progress Report)	24	12	300
2	**AM6192**	Progress Report Seminar & Viva-voce		6	100

Fourth Semester

Sl. No	Paper	Credit
1	M. Tech Final thesis	22
2	Thesis Seminar & Viva-voce	8
	Total Credit	**30**

Note:

1. For M. Tech Final thesis, the student will compile the entire work done for the M. Tech Project, along with the findings, in the form of a Thesis and submit at the end of the semester. Thesis submission will be followed by a Thesis seminar and Viva-voce.

M. Tech Project Part – III

Sl. No	Subject code	Subject Name	Total load (h)	Credit	Marks
1	**AM6291**	M. Tech Final thesis	30	22	400
2	**AM6292**	Thesis Seminar& Viva-voce		8	200

Total Credit: 21 + 21 + 18 + 30 = 90

Note on Subject Code:

XX: Department Code (AE, CE, ME, etc.); YY: Year(Y)-Semester(Y) (51, 52, 61, 62, etc.);

ZZ: Subject Code (01 to 49 for Theory subjects, 50-99 for practical subjects.

Example: AE5124 [Aerospace Engineering, Fifth Year (PG), First Semester, 24 subject code)

(For 2 year M.Tech Program in Applied Mechanics)
Specialisation: Mechanics of Solids
1st semester Paper-I (Departmental Core)
Subject: **Theory of Elasticity** (**AM5101)**

Contact Period**: 3L per week** Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

This course is intended to enhance the indepth knowledge to solve various engineering problems involving stress which can not be solved by simple theory of strength of materials. The subject will help to learn the process of determining actual nature of stress distribution in bodies involving sharp variation of geometry as well as loading frequently occurred in the field of Applied Mechanics relevant to Civil Engineering,Mechanical Engineering, Aerospace Engineering and other Engineering Disciplines due to tensile, bending, torsion, thermal loadings.

Expected Learning Outcomes for Course:

This course is made of particular interest, the graduate students, research scholars who will work to to determine complex nature of elastic stress distribution arising out of diffrent types of loading as well as gymetry.

Prerequisite : Basic knowledge of Rigid Body Mechanics, Stength of Materials, Partial Differentiation, Solution of Diferential Equations**,** Numerical Methods

Sl No.	Article	No. of Classes
1.	**Plane Stress and Plane Strain :**Introduction, Differential Equations of Equilibrium, Boundary Conditions, Compatibility Equations, Stress Function.	10
2.	**Two Dimensional Problems in Rectangular Coordinates:** Solutions by Polynomials, End Effects: Saint-Venant's Principle, Determination od Displacements, Bending of a Cantilever Loaded at the End, Bending of a Beam by Uniform Load.	10
3.	**Two Dimensional Problems in Polar Coordinates:**General Equations in Plar Coordinates, Stress Distribution Symmetric about an Axis, Displacements for Symmetrical Stress Distributions, Rotating Disks, The Effect of Circular Holes on Stress Distributions of Plates.	9
4.	**Three Dimensional Stress Analysis:** Cauchy Stress Tensor, Direction cosine and Force Resolution, Stress Transformations, Principal Stresses and Invariants	10
	Total	**39**

Books recommended:

1. Theory of Elasticity by S.P. Timoshenko & J.N. Goodier `
2. Theory of Elasticity by A. Maceri
3. Basic Engineering Plasticity,An introduction with Engineering and Manufacturing Applications by D.W.A. Rees.

For 2 year M.Tech Program in Applied Mechanics)

Specialisation: Mechanics of Solids (MOS)

1st semester Paper-II (Departmental Core)

Subject: **Theory of Vibration (AM5102)**

Contact Period: 3 L per week **Full Marks: 100 [Credit -03]**

Sl No.	Article	No. of Classes
1	Introduction to vibrating systems; Degrees of freedom; Lumped parameter system; Single degree of freedom system; Free undamped and damped vibration; Types of damping	**6**
2	Forced vibration of SDF system- undamped and damped system; Types of excitation – harmonic, periodic and arbitrary; Frequency domain and time domain analysis; Phase plane approach; Vibration isolation; Critical speed of rotating shaft	**12**
3	System with 2-DOF; Concept of natural mode – harmonic excitation and vibration absorber	**4**
4	MDF; Matrix methods; Orthogonality of normal modes; Modal analysis	**6**
5	Free vibration of elastic bodies – bars, shafts and beams	**6**
6	Approximate methods – Rayleigh's method, Rayleigh-Ritz's method	**3**
7	Measurement of vibration	**2**

Books:

W T Thompson, *Theory of Vibration with* Applications, George Allen

L Meirovitch, *Analytical Methods in* Vibration, MacMillan Publishers

(For 2 year M.Tech Program in Engineering Mechanics)
Specialisation: Mechanics of Solids (MOS)
1st semester Paper-III (Departmental Core)
Subject: **Finite Element Method in Solid Mechanics (AM 5103)**

Contact Period: 3L per week. Full Marks: 100, Pass Marks: 40 [Credit – 03]

Course objectives:

The Finite Element Method is a numerical method for solving complicated Engineering and Mathematical physics. This subject is used almost all branches of engineering. Knowledge of this subject is particularly useful in the field of Structural analysis, heat transfer, mass transfer, fluid flow, vibration of structures, lubrication, electromagnetic potential, optimization etc**.**

Expected Learning Outcomes for Course:

After successfully completing this course, students will:
- Understand non-linear Finite Element Methods.
- Understand how to solve 3-D problems.
- Understand the Fluid flow problems and other engineering problems.

Prerequisite: Strength of materials, Mechanics of plates and shells, Vibrations of Structures.

Sl.	Article	No. of classes
1	Transformation matrix and stiffness matrix of truss element in two dimensional and three dimensional systems. Two dimensional arbitrarily oriented beam element. Derivation of equivalent load vectors of beam element for concentrated load, uniform distributed load and linear varying distributed load. Related problems. Stiffness matrix of Timoshenko beam element. Rigid plane frame. Grid equations. Beam element arbitrarily oriented in space. Related Problems. Temperature effect on truss structures. Related problems	15
2	Principle of virtual work, principle of minimum potential energy of elastic body, The Rayleigh-Ritz method, Finite element form of the Rayleigh-Ritz method, Weighted residual method, Galerkin's finite element method.	8
3	Stiffness matrix of plane element. Bending theory of laminated composite materials: Finite element formulationof Kirchhoff and Mindlin plate theory. Stiffness matrix of laminated composite plate element.Isoparametric element.	8
4	Finite element in vibration: Finite element formulation. Derivation of lumped and consistent mass matrices of bar, beam and plane stress elements. Problems related to free vibration of beam and truss structures.	8

Total : 39 Hours

Books:

1. Concepts and Applications of Finite Element Analysis by R. D. Cook, D. S. Malkus and M. E. Plesha.
2. A First Course in the Finite Element Method by Daryl L. Logan.

(For 2 year M.Tech Program in Engineering Mechanics)
Specialisation: Mechanics of Fluids (MOF)
1st semester Paper-I (Departmental Core)
Subject:**: Viscous Fluid Flow** (**AM5106)**
Contact Period: 3L per week Full Marks: 100, Pass Marks: 40 [Credit – 03]

Sl No.	Article	No. of Classes
	Viscous Fluid Flow (AM5115)	
1.	Review of basic concepts: continuum hypothesis, strain rates, origin of forces in viscous fluid flow	4
2.	Dynamics of ideal fluid motion, applications, integrations of Euler's Equation of Motion, generalized form of Bernoulli Equation, potential flows, Principle of superposition.	4
3.	Reynolds transport theorem and applications	4
4.	Derivation of generalized differential continuity and momentum equations for viscous fluid flow in Cartesian and Curvilinear co-ordinates	6
5.	Some exact solutions of N-S equations- Steady and unsteady parallel flows: Couette-Poiseulle flow, parallel plates; Flow at very low Reynolds number- Stokes flow equations	6
6.	Boundary layer equations for two dimensional steady flow. Separation of boundary layer. Integration of boundary layer equations. General properties of boundary layer equations. Exact and approximate methods of the solution of two dimensional steady state incompressible boundary layer equations. Flow in the wake of flat plate zero incidence.	9
7.	Compressible laminar boundary layers and numerical study of compressible flows using density based *CFD* techniques	6
	Total	**39**

Books:

1. F.M.White, Viscous Fluid Flow, McGraw-Hill international editions., 2011.
2. H.Schlichting, Boundary Layer Theory, McGraw-Hill Series in Mechanical Engineering, 1979
3. An Introduction to Fluid Dynamics – G. K. Batchelor – Cambridge University Press, 2000.
4. T. C. Papanastasiou, G. C. Georgiou, A. N. Alexandrou, Viscous Fluid Flow, CRC Press, 2000

(For 2 year M. Tech Program in Engineering Mechanics)
Specialisation: Mechanics of Fluids (MOF)
1st Semester Paper-II (Departmental Core)
Subject: **Convective Heat Transfer (AM5107)**
Contact Period: 3L per week Full Marks: 100, Pass Marks: 40 [Credit – 03]

Course objectives:
This is one of the departmental core subjects of the specialisation of Mechanics of Fluids - intended to cover the fundamentals of Convection heat transfer from an advanced point of view, with emphasis on the analytical (mathematical) treatment of laminar flows in both internal and external flow configurations. We begin with the conservation equations for energy and its dimensionless form. Specific attention is given to the theory of thermal boundary layer, fully developed and developing internal flows, exact and approximate methods of the solution for steady-state, incompressible flows. We also delineate the basics of turbulent convection and natural convection in brief.

Expected Learning Outcomes for Course:
After successfully completing this course, students will:
- develop an understanding of the fundamentals of convective heat transfer – both physics and appropriate mathematical models.
- develop the ability of solving various engineering problems involving thermal convection.
- improve their overall knowledge of transport phenomena and analytical ability.

Prerequisite: Fluid Mechanics (knowledge of Navier-Stokes equation, Boundary layer theory). Assignments will involve solution of ODE and PDE. Reasonable programming proficiency in C and MATLAB will be required.

Sl No.	Article	No. of Classes
1.	**Introduction:** Different modes of heat transfer, Energy equation, Dimensionless form of energy Eq., Important dimensionless parameters in heat transfer	05
2.	**Forced convection in internal flow:** Thermally fully developed flow through circular ducts and parallel plate channels, uniform temperature and uniform heat flux boundary conditions; Thermally developing flow; Heat transfer with viscous dissipation	10
3.	**Forced convection in external flow:** Equations for hydrodynamic boundary layer and thermal boundary layer; Reynolds analogy; Scale analysis; Similarity solutions for thermal boundary layer; Integral method; heat transfer correlations	10
4.	**Turbulent forced convection and applications:** Time-averaged governing equations for turbulent boundary layers, thermal eddy diffusivity; Convection correlations for internal and external flows	06
5.	**Free convection:** Laminar natural convection along a vertical plate, exact solutions for constant wall temperature and constant wall heat flux; Integral solution; Free convection in enclosures; Combined free and forced convection	08
Total		**39**

Books:

1. Convective Heat and Mass Transfer *by* W M Kays & M E Crawford, McGraw-Hill
2. Fundamentals of Heat and Mass Transfer *by* Incropera, Dewitt, Bergman & Lavine, John Wiley & Sons, Inc.
3. Convection Heat Transfer *by* Adrian Bejan, Wiley-India.

<u>(For 2 year M.Tech Program in Engineering Mechanics)</u>

Specialisation: Mechanics of Fluids (MOF)

1st semester Paper-III (Departmental Core)

Subject: **Methods in Computational Fluid Dynamics (AM5108)**

Contact Period: 3L per week Full Marks: 100, Pass Marks: 40 [Credit – 03]

Course objectives:

Computational Fluid Dynamics (CFD) plays a major role in engineering design. These methods are used in every field starting from the design of aircrafts, automobiles, turbo machineries, biomedical instruments, etc This course has three objectives:

- Introduce basics of computational fluid dynamics and its applications
- Provide theoretical knowledge and practical knowledge about finite volume method in CFD;
- Provide knowledge in basic CFD programming

Expected Learning Outcomes for Course:

After successfully completing this course, students will:

- Understand the basic equations involved in CFD
- Understand the concepts of finite volume method
- Insight into the boundary conditions involved in CFD solvers
- Understand the pressure based CFD solvers and its significance
- Understand the flux calculation methodologies in density based solver
- Understand the structure of a CFD program

Prerequisite: Basic Fluid dynamics and mathematics

Sl No.	Module name and Topics	No. of Classes
1.	**Governing equations:** Basics of computational fluid dynamics – Governing equations of fluid dynamics – Continuity, Momentum and Energy equations – Physical boundary conditions – Mathematical behaviour of PDEs on CFD – Elliptic, Parabolic and Hyperbolic equations.– Grid generation and types - Finite Difference, Finite Volume, Finite Element Methods.	8
2.	**Finite volume method for incompressible flow:** Spatial Discretization - Convective and diffusive fluxes - Representation of the pressure gradient term and continuity equation – Staggered grid – Momentum equations – Pressure and Velocity corrections – Pressure Correction equation, SIMPLE algorithm and its variants – PISO Algorithms - QUICK Schemes.	9
3.	**Finite volume method for compressible flow :** Euler backward/forward time integration - Characteristics and Eigenvalues - Flux vector splitting methods - Godunov method and approximate Riemann solvers	8
4.	**Turbulence modelling:** Introduction to turbulence - scales of turbulence, Reynolds Averaged Navier Stokes (RANS) equation, closure problem, eddy viscosity model, k-ε and k-ω model - introduction to large eddy simulation (LES) - direct numerical simulation.	6
5.	**Numerical methods and programming practice:** Numerical methods – Programing and algorithm –1D heat conduction - 1D advection-diffusion – Flux schemes – 1D Euler solver.	8
Total		**39**

<u>Books</u>:

1. Chung, T.J. “Computational Fluid Dynamics”, Cambridge University, Press, 2002.
2. Blazek, Jiri. Computational fluid dynamics: principles and applications. Butterworth-Heinemann, 2015.
3. Anderson, John David, and J. Wendt. Computational fluid dynamics. Vol. 206. New York: McGraw-Hill, 1995.
4. Patankar, S.V. “Numerical Heat Transfer and Fluid Flow”, Hemisphere Publishing Corporation, 2004.
5. ProdipNiyogi, Chakrabarty, S.K., Laha, M.K. “Introduction to Computational Fluid Dynamics”, Pearson Education, 2005.
6. Anil W. Date “Introduction to Computational Fluid Dynamics” Cambridge University Press, 2005.

(For 2 year M.Tech Program in Engineering Mechanics)

Specialisation: Mechanics of Solid (MOS) / Mechanics of Fluids (MOF)

1st Semester Paper-IV (**DE**)

Subject: **Continuum Mechanics (AM5121)**

Contact Period: 3L per week   Full Marks: 100, Pass Marks: 40 [Credit – 03]

Course objectives:

- Provide a general framework unifying the seemingly diverse fields of Solid Mechanics and Fluid Mechanics
- Obtain the laws governing the behaviour of continuum in a coordinate frame free manner.

Expected Learning Outcomes from the Course:

After successfully completing this course, students will:

- Understand the basic foundation of mechanics
- Get exposure to finite deformation regime in Solid and Fluid Mechanics.

Prerequisite: Basic understanding of Engineering Mechanics, Mechanics of Materials

Sl No.	Article	No. of Classes
1.	**Mathematical Preliminaries:** Introduction, Vector space, Second Order Tensors, Higher Order Tensors, Symmetric Tensors, Skew-Symmetric Tensors, Orthogonal Tensors, Tensor Calculus: Differentiation of Tensors, Directional Derivatives, Gradient, Divergence and Curl, Integral Theorems	12
2.	**Kinematics:** Lagrangian and Eulerian Descriptions, Length, Area and Volume Elements in the Deformed Configuration, Velocity and Acceleration, Rate of Deformation, Examples of Simple Motions,	8
3.	**Balance Laws:** The First Transport Theorem, Conservation of Mass, The Second Transport Theorem, Balance of Linear Momentum, Balance of Angular Momentum, Properties of the Cauchy Stress Tensor, The Equations of Motion in the Reference Configuration, Energy Equation	9
4.	**Constitutive Relations:** Frame of Reference, Transformation of Kinematical Quantities, Principle of Frame-Indifference, Principle of Material Frame-Indifference, Material Symmetry, Classification of Materials, Linear Elasticity, Thermo-mechanics of Fluids	10
Total		**39**

Books:

1. C. S. Jog, Continuum Mechanics: Foundations and Applications of Mechanics, Volume I, Third edition, 2015, Cambridge University Press.
2. L.E. Malvern, Introduction to the mechanics of continuous medium, 1969, Prentice-Hall Inc.
3. R.C. Batra, Elements of Continuum Mechanics, 2005, AIAA Education Series

(For 2 year M.Tech Program in Applied Mechanics)
Specialisation: Mechanics of Solids (MOS)
1st Semester Paper-IV/V (DE)
Subject: **Mechanics of Composite Materials (AM5122)**

Contact Period: 3 L per week **Full Marks: 100 [Credit -03]**

Sl No.	Article	No. of Classes
1.	Introduction to composite materials: Definitions; constituent materials; terminologies; general characteristics; advantages and uses	**03**
2.	Manufacturing processes of composite materials: Contact moulding methods; compression moulding methods and filament winding	**03**
3.	Micromechanical analysis of composite strength and stiffness: Volume and weight fractions; longitudinal strength and stiffness; transverse modulus; inplane shear modulus and Poisson's ratio	**06**
4.	Elastic properties of unidirectional lamina: stress-strain relationship; engineering constants; transformation of stress and strain; transformation of elastic constants; transformation of engineering constants	**08**
5.	Analysis of laminated composites: strain-displacement relationship; stress-strain relations; equilibrium equations; laminate stiffness; determination of lamina stresses and strains; types of laminate configurations	**08**
6.	Analytical methods of laminated plate: Classical laminate plate theory; Bending of composite plates, Free vibration of composite plates	**05**
7.	Failure theories and strength of a unidirectional lamina: Micromechanics of failure of unidirectional lamina; anisotropic strength and failure theories	**04**
8.	Analysis of laminate strength: Possible modes of failure; strength analysis at first-ply failure; total-ply failure method; partial-ply failure method	**02**
Total		**39**

Books:

- Madhujit Mukhopadhyay, Mechanics of Composite Materials and Structures, Universities Press, 2004.
- R. M. Jones, Mechanics of Composite Materials, McGraw Hill, 1993.

<u>For 2 year M.Tech. Program in the Dept. of Aerospace Engg. &Applied Mechanics</u>

Specialisation: Mechanics of Solids

1st semester Paper-IV (DE)

Subject: **Biomechanics (AM5123)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

This course provides background of human musculoskeletal anatomy and principles of biomechanics. The course applies and builds on the concepts of statics and dynamics for human activities, and mechanics of materials and tissues.

Expected Learning Outcomes for Course:

After successfully completing this course, students will be able to apply knowledge of engineering, biology, and biomechanical principles to the design, development, and evaluation of biological systems and products, such as artificial organs, prostheses, instrumentation, and health care delivery systems.

Prerequisite: No prerequisite

Sl No.	**Article**	**No. of Classes**
1.	Introduction	1
2.	Human Musculo-skeletal Structure and its Function	5
3.	Hip Joint Mechanics	5
4.	Spine Mechanics	5
5.	Human Bone and its Properties	4
6.	Minimum Biomechanical Energy Principle for most Comfortable Posture	3
7.	Vehicular Occupant Response	3
8.	Flow through Artery	3
9.	Human Gait Analysis	4
10.	Function of Heart	3
11.	Flow through Catheter and its Response	3
	Total	**39**

<u>Books</u>:

- Basic Biomechanics: S. J. Hall
- Fundamentals of Biomechanics - Equilibrium, Motion, and Deformation: N.**Özkaya,** M.**Nordin,** D.**Goldsheyder,** D.**Leger**
- Biomechanics - Mechanical Properties of Living Tissues: Y.C. Fung
- Human Body Mechanics: D.N. Ghista

(For 2 year M.Tech Program in Engineering Mechanics)

Specialisation: Mechanics of Fluids (MOF)

1st Semester Paper-IV/V (DE)

Subject: Turbomachineries (AM 5126)

Contact Period: 3L per week Full Marks: 100, Pass Marks: 40 [Credit – 03] Prerequisite: No prerequisite

TURBOMACHINERY		
1.	**Unit I: Introduction to turbo machines:** Classification of Turbomachines, Comparison with positive displacement machines, Dimensionless parameters and their significance, Second Law of Thermo dynamics - turbine/compressor work, Fluid equations - Euler's, Bernoulli's equation and its applications, principles of impulse and reaction machines, degree of reaction.	8
2.	**Unit II: Energy exchange in turbo machines:** Euler's turbine equation, Alternate form of Euler's turbine equation, Velocity triangles for different values of degree of reaction, Components of energy transfer, Degree of Reaction, utilization factor, Relation between degree of reaction and Utilization factor	9
3.	**Unit III: Water turbines and pumps:** Classification, Pelton, Francis, and Kaplan turbines, velocity diagrams and work-done, draft tubes, governing of water turbines. ***Centrifugal Pumps:*** Classification and parts of centrifugal pump, different heads and efficiencies of centrifugal pump, Minimum speed for starting the flow, Maximum suction lift, Net positive suction head, Cavitation, Need for priming, Pumps in series and parallel, Slip factor	8
4.	**Unit IV: Gas turbines and Compressors:** ***Centrifugal Compressors***: Stage velocity triangles, slip factor, power input factor, Stage work, Pressure developed, stage efficiency and surging, Expansion and compression processes, Reheat Factor ***Axial flow Compressors:*** Expression for pressure ratio developed in a stage, work done factor, efficiencies and stalling. Problems. ***Axial turbine***-Description of operation, flow losses, turbine cooling, overall performance	9
5.	**Unit V: Fans and Blowers:** Introduction to fans and blowers, Flow through Axial flow fans, Principles of Axial fan, Application of fans for air circulation and ventilation, Stage pressure rise and work done, Performance and characteristics of Axial fans, Fan laws.	5
	Total	**39**

Books:

1. S.M. Yahya, Turbines, Compreessors and Fans, Tata Mcgraw Hill.
2. Gopalakrishnan G, Prithvi Raj D, "A treatise on Turbomachines", Scitech Publications, Chennai, 2002.
3. Sheppard, Principles of Turbomachinery.

R.K.Turton, Principles of Turbomachinery, E & F N Spon Publishers, London & New York.
Balajee, Designing of Turbomachines.
Venkanna BK; turbomachinery; PHI
Csanady; Turbo machines
Kadambi V Manohar Prasad; An introduction to EC Vol. III-Turbomachinery; Wiley Eastern Delhi

(For 2 year M.Tech. Program in Applied Mechanics)

Specialisation: Mechanics of Fluids (MOF)

1st semester Paper-IV/V (DE)

Subject: **Theory of Hydraulic Models (AM5127)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

Dimensional analysis plays a vital role in theory of hydraulic model. It treats the general forms of equations that describe natural phenomena. Applications of dimensional analysis abound in nearly all fields of engineering particularly in fluid mechanics and hydraulics. This course has the following objectives:

- To introduce a systematic and thorough treatment of the principles of dimensional analysis for the solution of different engineering problems.
- To provide knowledge in modelling and designing different types of problems
- To provide knowledge of a routine numerical procedure for calculating a fundamental system of solutions of any set of homogeneous linear algebraic equation.
- To provide knowledge in analyzing and implementing the real engineering problems

Expected Learning Outcomes for Course:

After successfully completing this course, students will:

- Understand how extensive use of scale-models for investigating problems of engineering raises many important questions that are resolved by dimensional analysis.
- Understand the method of deriving model laws from the differential equations that govern particular phenomena.
- Understand how the knowledge of this subject is also helpful in the analysis of problems of stress and strain
- Be able to find the applications of dimensional analysis to some thermal problems.
- Be able to have the ideas underlying the dimensions of electrical and magnetic entities to solve the problems applied to the electromagnetic theory.

Prerequisite: Hydraulics, Fluid Mechanics and Fluid Machines

Sl No.	Article	No. of Classes
1.	General: Dimensional considerations, algebraic theory of dimensional analysis, Buckingham's theorem and Rayleigh's method of analysis-application to standard problems, standard dimensionless numbers, dimensional matrix and its rank, systematic calculation of dimensionless products. Distorted models of open channels. Dimensional analysis applied to the theory of heat.	12
2.	Similitude: Kinds of similarity, similitude requirement, conditions for incompressible and compressible fluids, model laws from differential equations.	08
3.	Similarity in hydraulic machinery, surge tanks, flow over weirs and spillways, flow through sluice gates, water and wind tunnel model and cavitation model.	11
4.	Analogue models: Electrical analogy model, Hele-Shaw model and Membrane analogy model.	08
	Total	**39**

Book: 1. Dimensional Analysis and Theory of Models by Henry L. Langhaar 2. Theory of Hydraulic Model by M. Selim Yalin

<u>(For 2 year M.Tech. Program in Applied Mechanics)</u>

Specialisation: Mechanics of Fluids

1st semester Paper-IV/V (DE)

Subject: **Water Wave Mechanics and Coastal Processes (AM5128)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

(i) To develop an understanding on water wave mechanics as applied to coastal engineering and introduce the different theories associated to waves, energy propagation in waves, shoaling, refraction, diffraction, and breaking.

(ii) To develop an intuitive feeling about the design concepts in coastal process based on understanding the different terms associated in the quantification and understanding the waves.

(iii) To discuss basic principles of water wave mechanics regarding wave energy and momentum, and their effects on wave transformation.

(iv) To understand the basic processes associated with wave sediment interaction in the coastal region.

Expected Learning Outcomes for Course:

After successfully completing this course, students will have:

(a) An ability to design and conduct experiments, as well as to analyze and interpret data associated with water waves.

(b) An ability to identify, formulate and solve engineering problems associated to coastal processes.

Prerequisite: Fluid mechanics, Differential equations

Sl No.	Article	No. of Classes
1.	Definition and characteristics of waves: Orbital motion, Wave energy, Wave height, Generation of waves and its types, Wave measurement and instrumentation in the sea and Coastal region.	3
2.	Review of hydromechanics, Introduction to Wave theory, Classification of wave theories	3
3.	Small amplitude water-wave theory:Boundary value problems- The governing differential equation, Boundary conditions- Kinematic boundary condition, Bottom boundary condition, Kinematic free surface boundary condition, Dynamic free surface boundary condition, Lateral boundary conditions.	7
4.	The two-dimensional periodic water wave boundary value problem, Solution to linearized water wave boundary value problem for a horizontal bottom,Solution by separation of variables, Application of boundary conditions,Standing waves, Progressive waves, Shallow and deep water wave; Dispersion relationship in shallow and deep water,Waves with uniform current.	7
5.	Wave kinematics, Water particle kinematics for progressive and standing wave,Particle velocity components,Particle displacements,Water particle trajectories for different relative depths, Water particle kinematics for standing wave, Velocity components,Particle displacements, Pressure field under progressive and standing wave	4
6.	Energy and energy propagation in progressive wave: Potential energy,Kinetic energy,Energy flux,Conservation of energy; Group velocity	3
7.	Transformation of waves entering in shallow water: Incident wave, Wave shoaling, Wave breaking, Wave refraction, Diffraction, Combined refraction-diffraction. Waves breaking in shallow water, Wave group	3
8.	Introduction of coastal zone: Definition and types, Coastal shore processes, Sediment transport mechanism, Bed forms	3
9.	Waves over real sea beds, Waves over smooth, rigid, impermeable bottom, Water waves over a viscous mud bottom	3
10.	Design of experiment in wave tank: Types of wave tank and flume, Types of wave maker, Wave absorbers, Instrumentation,Flow, Bathymetry, and Pressure measurement, Data handling and analysis for waves in turbulent flow	3

Total	39

Books:

1. Water Wave Mechanics for Engineers and Scientists by Dean and Dalrymple
2. Introduction to Coastal Engineering and Managementby J. William Kamphuis
3. Introduction to Coastal Processes and Geomorphologyby Robin Davidson-Arnott
4. Wave Mechanics for Coastal Engineering by Paolo Boccotti
5. Basic Coastal Engineering by Robert M. Sorensen

(For 2 year M.Tech. Program in Applied Mechanics)

Specialization: Mechanics of Fluids

1st semester Paper-IV/V (DE)

Subject: **Computational Aerodynamics (AM 5129)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

Basic intension of this course is to expose the students to a variety of low speed flow problems. The flow is essentially incompressible and inviscid and the problem can be described by linear Laplace equations. The course is to introduce the students with small disturbance flow with airfoils and wings and corresponding solution techniques.

Expected Learning Outcomes for Course:

After successfully completing this course, students will have the basic idea which ultimately leads to numerical computational aerodynamics.

Prerequisite: Basic understanding of Potential Flow

Sl No.	Article	No. of Classes
1	• Small –Disturbance Flow over Three-Dimensional Wings: Definition of the Problem; Boundary Condition on the Wing; Separation of Thickness and lifting Problem; The Aerodynamic Loads; The Vortex Wake.	13
2	• Small –Disturbance Flow over Two-Dimensional Airfoils: Symmetric Airfoil with Non-zero Thickness at Zero Angle of Attack; Zero Thickness at Angle of Attack; Classical Solution of the Lifting Problem; Aerodynamic Forces and Moments; The Lumped Vortex Element.	13
3	• Perturbation Methods: Thin Airfoil Problem; Second Order Solution; Leading Edge Solution; Method of Assymptotic Expansion; Thin Airfoil between Wind-Tunnel Walls.	13
	Total	**39**

Books recommended:

1. Katz and Plotkin, Low-Speed Aerodynamics, Cambridge

(For 2 year M.Tech. Program in Applied Mechanics)

Open Elective

1st semester Paper-IV/V (OE)

Subject: **Mechatronics (AM5161)**

Periods – 3L per week, Full Marks – 100, Semester Examination - 70,
Internal Assessment - 30, Pass Marks - 40 Time - 3 hrs., Credit – 03, Prerequisite - None

Course Description: Mechatronics is the synergistic combination of mechanical engineering, electronics, control engineering, and computers, all integrated through the design process. It involves the application of complex decision making to the operation of physical systems. Mechatronic systems depend for their unique functionality on computer software. This course studies mechatronics keeping application specific to product development at a theoretical and practical level; balance between theory/analysis and hardware implementation is emphasized; emphasis is placed on physical understanding rather than on mathematical formalities. A case study, problem-solving approach, with video hardware demonstrations, is used throughout the course.

Course objective: This course is intended for learning the fundamentals of mechatronics functions involved in product development which is the synergistic integration of many aspects of engineering knowledge base in precision mechanics, electronics, control and computer systems.

Contribution of the course to meet professional component: Create genuine interest and ability across a wide range of technologies which will provide the most economic, elegant and appropriate solution to the problem in hand. Intelligent systems are genuine mechatronics artefacts characterized by the synergistic integration of their mechanical, electromechanical, and electronic components, as well as built-in informational constituents in the form of microcontrollers. Design of such systems is complicated, as the conventional decoupled or loosely-coupled approaches can hardly provide optimal or even sub-optimal solutions. The primary objective of the subject is to develop systematic frameworks and modular, hierarchical architectures for the concurrent, detail-level engineering of simple systems, from conception to configuration to integration to realization and implementation, by using the expert's knowledge base through the object-oriented hardware-in-the-loop simulations including Matlab and LabVIEW. Throughout the coverage the focus is kept on the role of each of these areas in the overall design process and how these key areas are integrated into a successful mechatronic system design. Starting at design and continuing through manufacture, mechatronic designs optimize the available mix of technologies to produce quality precision products and systems in a timely manner with features the customer wants. If winning designs are to be produced in today's environment, it is imperative that electronics and computer control be included in the design process at the same time the basic functions and properties are defined. The real benefits to industry of a mechatronic approach to design are shorter development cycles, lower costs, and increased quality, reliability, and performance.

Sl No.	Article	No. of Class
1.	**Mechatronics:** What is Mechatronics? Mechatronics Systems, Measurement systems, Control systems, Microprocessor-based controllers, response of systems, Mechatronics approach.	3
2.	**Sensors and transducers:** Sensors and transducers, Performance terminology, Displacement, position and Proximity, Force, Fluid Pressure, Liquid Flow, Liquid level, Selection of sensors.	2
3.	**Signal conditioning:** Signal conditioning, The Operational amplifier, Wheatstone bridge, Digital signals, Data acquisition, Digital Signal Processing.	2
4.	**Pneumatic and hydraulic actuation systems:** Actuation systems, Pneumatic and hydraulic systems, Directional control valves, Pressure control valves, Cylinders, Process control valves, Rotary actuators.	4
5.	**Mechanical actuation systems:** Mechanical systems, Types of motion, kinematic chains, Cams, Gear trains, rachet and pawl, Belt and chain drives, Bearings, Mechanical aspects of motor selection problems.	3
6.	**Electrical actuation systems:** Electrical systems, Mechanical switches, D.C. motors, A.C. motors, Stepper motors.	2
7.	**Basic system models:** Mathematical models, Mechanical system building blocks, Electrical system building blocks, Fluid system building blocks, Thermal systembuilding blocks,	3
8.	**System models:** Engineering Systems, Rotational–translational systems, Electromechanical Systems, Hydraulic mechanical systems.	2
9.	**Dynamic responses of systems:** Modeling dynamic systems, First-order systems, Second-order systems.	2
10.	**System transfer functions:** The transfer function, First-order systems, Second-order systems.	2
11.	**Frequency response:** Sinusoidal input, Frequency response, Bode plots.	1
12.	**Closed-loop controllers:** Continuous and discrete control processes, Control modes, Proportional mode, Derivative control, Integral control, PID controller, Adaptive control.	2
13.	**Microprocessors:** Microprocessor systems, Microcontrollers, Applications.	2
14.	**Input/output systems:** Interfacing, Input/output addressing, Serial communications interface, Examples of interfacing.	1
15.	**Programmable logic controllers:** Programmable logic controller, programming.	2
16.	**Communication systems:** Digital communications.	2
17.	**Mechatronics systems:** Traditional and Mechatronics designs, Possible Mechatronics design solutions, Case studies of mechatronic systems.	4
	Total	**39**

Books:

1. Mechatronics - by W. Bolton (Pearson) 2. Mechatronics - An introduction by Robert H. Bishop (Taylor & Francis) 3. Mechatronics System design - by Shetty and Kolk (Cengage) 4. Mechatronics - an integrated Approach by Clarence W. de Silva (CRC Press)

<u>**(For 2 year M.Tech. Program in Applied Mechanics)**</u>

Open Elective

1st semester Paper-IV/V (OE)

Subject: **Human Body Mechanics (AM5162)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

This course will help students to understand how mechanics is involved in the human body from unit cell structure to the overall skeletal system. Students can also understand the role of fluid mechanics in the circulatory system of the human body.

Expected Learning Outcomes for Course:

After successfully completing this course, students will be able to apply knowledge of engineering, biology, and biomechanical principles to the design, development, and evaluation of biological systems and products, such as artificial organs, prostheses, instrumentation, and health care delivery systems. **Prerequisite: No prerequisite**

Sl No.	Topic	No. of Hours
1.	Human Body Mechanics: definition and perspective	2
2.	Quantitative versus qualitative problems, Structure, movements and loads on the shoulder, Structure, movements and loads on the elbow and wrist, Structure, movements and loads on the hip, Structure, movements and loads on the knee, Structure, movements and loads on the spine, Structure, movements and loads on the foot, Common injuries in shoulder, elbow wrist, hip knee, spine and foot	8
3.	Equilibrium and Torque, Resultant Joint Torques, Levers, Anatomical levers, Equations of static and dynamic equilibrium, Center of gravity and locating the center of gravity, Locating the human body Center of Gravity, Stability and balance	4
4.	Stress in three-dimensional continuous media	5
5.	Properties of Bone, Maxwell & Voight Models of bone, Biomechanics of human skeletal muscle, Biomechanics of human Skeletal Articulations	3
6.	Material Characterization of Tissues: Classification of Tissues, Properties of Tissues from Mechanics Point of View, Modeling of Tissues	3
7.	Mechanical Property of the Human Body Material components of the body and their elastic properties, time-independent deviations in hookean materials, static equilibrium of deformable bodies, time-dependent deviations from elastic behavior: viscoelasticity, viscoelasticity in bone, bone fractures, common sports injuries, avoiding fractures and other injuries: materials for helmets	6
8.	Motion: The time as an extra dimension	2
9.	Deformation and rotation, deformation rate and spin	2
10.	Cardiovascular Mechanics: Cardiovascular Physiology, Blood Flow Models, Blood Vessel Mechanics, Heart Valve Dynamics, Prosthetic Valve Dynamics	4
Total		**39**

<u>**Books**</u>:

- Basic Biomechanics: S. J. Hall
- Fundamentals of Biomechanics - Equilibrium, Motion, and Deformation:N.Özkaya**,** M.Nordin**,** D.Goldsheyder**,** D.Leger
- Biomechanics - Mechanical Properties of Living Tissues: Y.C. Fung
- Human Body Mechanics: D.N. Ghista

(For 2 year M.Tech Program in Engineering Mechanics)
Specialisation: **Mechanics of Solids (MOS)**
2nd semester Paper-VI (Departmental Core)
Subject: **Theory of Plasticity** (**AM5201)**

Contact Period**: 3L per week** Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

This course is intended to enhance the synergistic research efforts on plasticity and failure mechanisms of advanced materials in Applied Mechanics relevant to Mechanical Engineering, Material Science and Engineering, Aerospace Engineering, Civil Engineering and other Engineering disciplines due to tensile, bending, torsion, fatigue, thermal loadings.

Expected Learning Outcomes for Course:

This course is made of particular interest, the graduate students, research scholars who will work on project based on their research topics of plasticity, cyclic plasticity, fracture mechanics, low cycle fatigue, ratcheting, crack growth, micromechanical modelling of materials,crystal plasticity based simulation etc.

Prerequisite : Mechanics of Solids**,** Numerical Methods

Sl No.	Article	No. of Classes
1.	**Introduction:** Large Strain Definitions, Finite Strain Tensors, Polar Decomposition	04
2.	**Yield Criteria:** Yielding of Ductile Isotropic Materials, Experimental Verification, Anisotropic Yielding in Polyerystals	02
3.	**Non-Hardening Plasticity:** Classical Theories of Plasticity of Hencky-Ilyushin, Prandtl-Reuss, Application of Classical Theory to Uniform Stress States, Thick-Walled, Pressurised Cylinder with Closed-Ends	04
4.	**Elastic-Perfect Plasticity:** Elastic-Plastic Bending of Beams,Shape Factor, Load Factor, Plastic Hinge, Residual Bending Stresses, Influence of Hardening, Elastic-Plastic Torsion of Solid Cylinder, Residual Shear Stress, Residual Angular Twist	06
5.	**The Flow Curve:** Equivalent Stress of von-Mises and Drucker, Equivalent Plastic Strain, Uniaxial Tests under Tension and Torsion	02
6.	**Plasticity With Hardening**: Conditions Associated with the Yield Surface, Loading Function, Drucker's Postulate, Isotropic Hardening, Levy-Mises, Drucker Theory, Non-Associated Flow Rules, Kinematic Hardening, Bauschinger Effect, Translation Rules, Reversed Yield Stress, Reversed Flow Curve, Plastic Instability	04
7.	**Classical Elasto-Plasticity and One Dimensional Cyclic Plasticity Model:** Classical One Dimensional Model of Elasto-Plasticity: Yield function, Flow rules and Hardening Laws; Kuhn-Tucker Conditions; Softening and Hardening Material Behaviors; One Dimensional Cyclic Plasticity; Kinematic Hardening Rules of Armstrong and Frederick and Chaboche. Isotropic Hardening, Combined Hardening, Plastic Multiplier, Hardening Modulus in One	05

	Dimension, One Dimensional Viscoplasticity, Return Mapping Algorithm.	
8.	**Three Dimensional Model of Cyclic Plasticity:** Three Dimensional Model of Plasticity, Dissipation Inequality, Plastic Multiplier, Tangent Operator, Hardening Modulus, Return Mapping Algorithm, Consistent Tangent Operator, Finite Strain Elasto-Plasticity, Multiplicative Decomposition of the Deformation Gradient, Additive Decomposition of Rate of Deformation.	05
9.	**Crystal Plasticity:** Resolved Shear Stress and Strain, Lattice Slip Systems, Hardening of Single and Polycrystals, Schmid's Law,Slip Systems, Kinematics of Crystal Deformation,Hardening of Single Crystals,Integration of the Elastoplastic Equations	05
10.	**Cyclic Plasticity Simulation:** Material Modelling with Plasticity in ABAQUS/ANSYS, Programming, Simulation.	02
	Total	**39**

Books recommended:

1. Basic Engineering Plasticity,An introduction with Engineering and Manufacturing Applications by D.W.A. Rees.
2. Computational Inelasticity by J.C. Simo and T.J.R. Hughes, Springer, 1998., ISBN: 0387975209
3. Mechanics of Deformable Solids: Linear, Nonlinear, Analytical and Computational Aspects,Issam Doghri,Springer,2000
4. Introduction to Computational Plasticity by Fionn Dunne and Nik Petrinic
5. Continnum Mechanics and Plasticity by Han-Chin Wu
6. Plasticty Theory by J. Lubliner
7. Continuum theory of defects by E. Kroener
8. Studies in large plastic flow and fracture by P W Bridgman.
9. Dislocations and plastic flow in crystals by A. H. Cottrell.
10. Fundamentals of the theory of plasticity by L. M. Kachanov.

(For 2 year M.Tech Program in Applied Mechanics)
Specialisation: Mechanics of Solids (MOS)
2nd semester Paper-VII (Core)
Subject: **Theory of Elastic Stability** (**AM5202)**

Contact Period**: 3L per week** Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

The course is intended to enhance the indepth knowledge to solve different types of structural stability problems primarily arising out from use of thin sectioned structural materials. This type of structural instability essentially lead to service falure of the structure that is it's inability to carry the intended load without causing any material damage. The course will help to asses Elastic Stuctural Stability which is an essential component of structural design particularly for thin walled structures used in the field of Civil Engineering, Mechanical Engineering andAerospace Engineering.

Expected Learning Outcomes for Course:

This course is made of particular interest, the graduate students, research scholars who will work in the field of stability assessment of structures under diffrent types of loading as well as gymetry.

Prerequisite :Knowledge of Stength of Materials, Partial Differentiation, Solution of Diferential Equations**,** Numerical Methods and Concept of Theories of Elasticity.

Sl No.	Article	No. of Classes
1.	**Stability of Beam-Column:**Introduction, Differential Equations, Beam-columns with Concentrated and continuous lateral Loads, Bending of Beam- columns under couples, Approximate formula for deflections, Determination of Allowable stresses.	10
2.	**Elastic Buckling of Frames and Bars:** Buckling of Frames, Buckling of Cuntinuous Beams, Energy Method for calculation of critical loads, Buckling of Bars on Elastic Supports.	12
3.	**Torsional Buckling:** Introduction, Pure and Nonuniform torsion of thin walled bars of open cross section, Torsional Buckling, Buckling by Torsion and Flexure.	10
4.	**Lateral Buckling of Beams:** Differential Equations, Lateral Buckling of beams under Pure bending. Lateral Buckling of thin walled cantilever and simpli-supported beams.	7
	Total	**39**

Books recommended:

11. Theory of Elastic stability by S.P. Timoshenko & J. M. Gere
12. Theory of Elastic Stability: Analysis and Sensitivity by Luis A. Godoy
13. Stability of Elastic Structures by N.A. Alfutov
14. Fundamentals of Structural Stability by Dewey H. Hodges and George J. Simitses

For 2 year M.Tech Program in Applied Mechanics
Specialisation: Mechanics of Solids (MOS)
2nd Semester Paper-VIII (Core)
Subject: **Mechanics of Plates and Shells (AM5203)**

Contact Period: **3L per week** Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

Extensive application of plates and shells are found in aerospace, machine tools, vessels, bunkers, silos etc.
This course provides basic theoretical knowledge for designing and implementing for real systems.

Expected Learning Outcomes for Course:

After successfully completing this course, students will be able to:

• Analyse and design plate and shell components of various structures.
• Have concept for writing codes and using dedicated software.

Prerequisite: No prerequisite

Sl No.	Article	No. of Classes
	Plates	
1.	Introduction to plates – Variety of plates – Kirchhoff's assumption to thin plates. Bending of long rectangular plates to a cylindrical surface: SS and Built-in edges. Pure bending of plates: relation between bending moment and curvature. Equilibrium of plate element under twisting moment.	5
2.	Small deflection of laterally loaded plate : differential equation of deflection surface, boundary conditions [SS edge, clamped edge, free edge, elastically supported edge]	3
3.	SS rectangular plate: under sinusoidal loading, Navier Solution and its further application. Levy's method for solution of transversely loaded rectangular plate for various end conditions. Analysis of plate with elastic foundations.	7
4.	Symmetrical bending of circular plate: axis-symmetric problems of various nature.	3
5.	Approximate methods of plate solution : Rayleigh, Raleigh – Ritz, Galerkin	6
6.	Basic analysis of orthotropic plate. Governing equation and solution of plates with in-plane loading. Basic solution of uniaxial and biaxial buckling of thin rectangular plate. Governing equation of thermal stress of plate	6
	Shells	
7.	Introduction to shells – membrane theory of symmetrically loaded shells of revolution and various applications.	5
8.	Membrane theory of cylindrical shells. Analysis of circular cylindrical shells with symmetric loading and applications	4
	Total	**39**

Books:

1. Theory of Plates and Shells by Timoshenko and Woinowsky-Krieger (TMH)
15. 2. Thin Plates and Shells by Ventsel and Krauthammer (Marcel Dekker Inc.)

(For 2 year M.Tech Program in Applied Mechanics)
Specialisation: Mechanics of Fluids (MOF)
2nd semester Paper-VI (Core)
Subject: **Fluid Power Control System (AM5215)**

Contact Period: 3L per week, Full Marks: 100, Pass Marks: 40 [Credit – 03] , Prerequisite: No prerequisite

Course objectives:

Fluid power plays an important role in many sectors of the economy. It is used in aerospace, machine tools, off-road vehicles,
material testing systems etc.
This course has three objectives:

- Introduce fluid power components, circuits, and systems
- Provide theoretical knowledge in designing, analyzing and implementing control systems for real and physical systems;
- Provide knowledge in modeling, control and other dynamical systems concepts.

- Understand hazards of hydraulic and pneumatic circuits and be able to work safely.
- Understand the concepts of fluid statics and dynamics as applied to commercial and industrial control.
- Recognize standard schematic symbols for common fluid power components.
- Understand and troubleshoot basic fluid power, electro-hydraulic, and electro-pneumatic circuits using schematic diagrams.
- Understand the operation, application, and maintenance of common fluid power components such as pumps, compressors, valves, cylinders, motors, rotary actuators, accumulators, pipe, hose, and fittings.
- Be able to find component application data online.
- Be able to select components from manufacturer's catalogs.

Sl No.	Article	No. of Classes
	HYDRAULICS	
1.	**Fluid Power Systems and Fundamentals:** Introduction, Advantages of Fluid Power, Disadvantages of Fluid Power systems, Applications of Fluid Power Systems, Types of Fluid Power Systems, Hydraulic Fluids, Fluid Characteristics	2
2.	**Hydraulic Systems and Components:** Sources of Hydraulic Power, Pumping Theory, Pump Classification, Gear Pumps, Vane Pumps, Piston Pumps.	3
3.	**Fluid Power Actuators:** Hydraulic Actuators, Hydraulic Cylinders, Hydraulic Motors.	2
4.	**Hydraulic Elements in the Design of Circuits:** Introduction to the design of Hydraulic Circuits, Control elements, Direction Control valve, Check Valves, Flow Control and Pressure Control valves.	3
5.	**Accumulators and Intensifiers:** Function of Accumulators, Types of Accumulators, Accumulator-Applications and Circuits, Intensifiers.	2
6.	**Design and Drawing of Hydraulic Circuits**	4
7.	**Fluid Power in Machine Tools and Other Equipment:** Introduction, Hydraulic Clamping Circuits in machine Tools, Speed Control in One Direction (DCV and FCV Combination), Meter-in Feed Circuit (DCV and FCV Combination), Meter-out Circuit DCV and FCV Combination), Speed Control in Both Directions (DCV and FCV Combination)— Tank Line Feed Control, Hydraulic circuit for Plastic Injection Moulding Machine, Hydraulic Press Application.	4
	PNEUMATICS	
8.	**Pneumatic systems-Concepts and Components:** Introduction, Comparison of Pneumatic/Hydraulic/ and	4

	Electrical Systems, Air-Compression System, Types of Compressors, Compressor Specifications, Arrangement of a Complete Pneumatic System, Understanding Pneumatic Circuits, Direction Control Valves	
9.	**Design of Pneumatic Circuits:** Fluid Power Circuit Design (Pneumatics), Control Air vs Signal Air, Building a Pneumatic Circuit, Speed control Circuits, Position Sensing in Pneumatic Cylinders, Pressure Sensing in Pneumatic Circuits.	3
10.	**Electropneumatics:** Pilot-operated Solenoid Valve, Electrical Connections to the Solenoids, Electrical limit Switches and Proximity Switches, Relays, Solenoids.	3
	APPLICATIONS OF HYDRAULICS AND PNEUMATICS	
11	**Servo and Proportional Systems:** Introduction, Closed-loop control with Servo System, Hydromechanical Servo System, Electrohydrolic Servo Valve System, Conventional Valves vs Proportional Valves, Proportional Valves, Proportional Valves in Hydraulic Circuits, Characteristics of proportional Valves and Servo Valves.	5
12.	**PLC applications in Fluid Power:** Introduction, Logic in Ladder Diagrams and Mnemonics.	2
13.	**Failure and Troubleshooting in Fluid Power Systems:** Troubleshooting-Oil Hydraulics, Troubleshooting- Pneumatics	2
	Total	**39**

Books:

1. Introduction to Hydraulics and Pneumatics by Ilango and Soundararajan (PHI) 2. Hydraulics and Pneumatics by Jagadeesha T (I.K. international) 3. Hydraulic and Pneumatic Controls by R Srinivasan 4. Pneumatics Systems: Principles and Maintenance - S Majumdar

(For 2 year M.Tech Program in Applied Mechanics)

Specialisation: Mechanics of Fluids

2ndsemester Paper-VII (Core)

Subject: **Theory of Turbulence (AM5216)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

- Introduce the basic properties of turbulence: Random fluctuating structures over a large range of length- and time-scales.
- Introduce the importance of turbulent mixing and transport of momentum in practical flows.
- Expose the students to theoretical and experimental techniques used to describe and quantify the effects of turbulence

Expected Learning Outcomes for Course:

- Students will become familiar with fundamental physics of turbulent flows.
- Students will become familiar with transport of moment, energy and vorticity in turbulent flows.
- Students will become familiar with the applications of turbulence in industry and environment.
- Students will be able to analyze simple shear, wall bounded and boundary layer flows with the use of phenomenological models of turbulence.
- Students will become familiar with different turbulence modelling techniques

Prerequisite: Fluid mechanics, Differential equations

Sl. No.	Article	No. of Classes
1.	The transition to turbulence: Experiments of Taylor, Benard and Reynolds. Role of the non-linear term of the Navier Stokes equation. Introduction to instability theory in the context of transition to turbulence.	4
2.	The statistical description of turbulent flows: the random nature of turbulence, characterization of random variables, probability distributions, joint random variables, random process, probability and averaging, correlation time, correlation length, two point correlation, Fourier modes	4
3.	The scales of turbulent motion, the energy cascade and Kolmogorov hypothesis, Energy spectrum	3
4.	Reynolds equation of motion in Cartesian and cylindrical coordinates, Reynolds stress tensor, the closure problem of turbulence	3
5.	Reynolds stress equation, Kinetic energy equation of the mean motion and the fluctuating motion, Energy transfer between the mean motion and the fluctuating motion, intercomponent transfer of energy, role of pressure, dissipation equation	6
6.	Vortex terms in the equation of motion, Reynolds stress and vortex stretching, The vorticity equation, Vortex line, Vortex tube, Vorticity in turbulent flows	3
7.	Wall flows: balance of mean forces, near wall shear stress, mean velocity profile, the law of the wall, the log law, the wall region and different layers, the velocity defect law, length scales and mixing length	5
8.	Free shear flows, Plane turbulent free jet: experimental observations, equations of motion, the integral momentum equation, similarity analysis of the equations of motion, the integral energy equation, entrainment hypothesis, integral moment of momentum equation.	5
9.	Introduction to turbulence modelling: eddy viscosity model, one equation turbulence models, two equation turbulence models	6
Total		**39**

<u>**Books**</u>:

1. Tennekes& Lumley (Main): A first course in turbulence (1972)
2. Steven A. Pope (Supplementary text): Turbulence, Cambridge (2004).
3. P. A. Davidson (Secondary text): Turbulent Flows, Oxford (2000)

(For 2 year M.Tech Program in Engineering Mechanics)

Specialisation: Mechanics of Fluids (MOF)

2nd Semester Paper-VIII (Departmental Core)

Subject: **Compressible Flow** (**AM5217)**

Contact Period: 3L per week Full Marks: 100, Pass Marks: 40 [Credit – 03]

Sl No.	Article	No. of Classes
1	**One Dimensional Flow:** One Dimensional Flow revisited; Hugoniot Equations; One Dimensional Flow with Heat Transfer; One Dimensional Flow with Friction. Problems.	04
2	**Two Dimensional Flow:** Two Dimensional Flow revisited; Shock Polar; Shock Reflection and Intersection; Bow Shock in front of a Blunt Body; Three Dimensional Shock Waves; Prandtl-Meyer Expansion Waves; Shock-Expansion Theory. Problems.	07
3	**Quasi-One Dimensional Flow:** Quasi-One Dimensional Flow revisited; Nozzles; Diffusers. Problems.	06
4	**Unsteady Wave Motion:** Introduction; Moving Normal Shock Waves; Reflected Shock Waves; Elements of Acoustic Theory; Finite Waves; Incident and Reflected Expansion Waves; Shock tube Relations; Finite Compression Waves.	06
5	**Linearised Flow:** Introduction; Differential Conservation equations for Inviscid Flow; Crocco's Theorem; Velocity Potential Equation: Linearised Velocity Potential Equation; Linearised Subsonic Flow; Linearised Supersonic Flow; Method of Characteristics.	06
6	**Three Dimensional Flow:** Cones at Angle of Attack; Blunt Bodies at Angle of attack.	04
7	**Numerical Techniques**: Steady and Unsteady Supersonic Flow	06
	Total	**39**

Books recommended :

1. J. D. Anderson Jr., Modern Compressible Flow with Historical Perspective, McGraw Hill
2. A H Shapiro, Dynamics and Thermodynamics of Compressible Fluid Flow- Volume I& II, Ronald Press
3. H W Liepmann and A Roshko,Elements of Gas Dynamics, John Wiley & Sons

(For 2 year M.Tech Program in Engineering Mechanics)

Specialisation: Mechanics of Solid (MOS) / Mechanics of Fluids (MOF)

2nd Semester Paper-IX/X (**DE**)

Subject:**: Engineering Optimization (AM5232)**

Contact Period: 3L per week   Full Marks: 100, Pass Marks: 40 [Credit – 03]

Course objectives:

Optimization plays an important role in all disciplines of Engineering. Any design/planning activity in Engineering is essentially an optimization seeking process.

This course has three objectives:

- Introduce the basic notion of optimization and the different types of Optimization problems encountered in Engineering.
- Introduce basic strategies of handling Unconstrained and Constrained Optimization problems
- Introduce non-traditional techniques of approaching Optimization problems.

Expected Learning Outcomes from the Course:

After successfully completing this course, students will:

- Learn to formulate basic Optimization problems in Engineering.
- Identify the nature of the problem formulated and apply suitable solution techniques.

Prerequisite: Knowledge of Undergraduate Engineering Mathematics

Sl No.	**Article**	**No. of Classes**
1.	**Unconstrained Optimization**: Introduction, Preliminary concepts, Fibonacci Method, Golden Section Search, The Steepest Descent Method, Conjugate Gradient Method, Newton's Method, Quasi-Newton Methods, BFGS Method	12
2.	**Linear Programming Problem:** Introduction, Geometric Concepts, Simplex Method, RevisedSimplex Method, Duality in Linear Programming, The Dual Simplex Method, Sensitivity Analysis	8
3.	**Constrained Optimization:** KKT Conditions, The Generalized Reduced Gradient Method, Sequential Quadratic Programming (SQP), Exterior and Interior Penalty Functions, Augmented Lagrange Multipliers,	8
4.	**Non-Traditional Techniques :** Genetic Algorithm (GA), Artificial Neural Network (ANN), Particle Swarm based approaches to Optimization, Simulated Annealing, Solving typical examples using MATLAB	11
	Total	**39**

(For 2 year M.Tech Program in Applied Mechanics)
Specialisation: Mechanics of Solids (MOS)
2nd semester Paper IX/X (DE)
Subject: **Engineering Fracture Mechanics (AM5234)**

Contact Period**: 3L per week** Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:
The objective of the course are understanding and exposure to linear elastic and elastoplastic fracture mechanics, dynamic and time dependent fracture mechanics, viscoelastic fracture mechanics, fatigue crack growth, fracture toughness testing and computational fracture mechanics.

Expected Learning Outcomes for Course:
The students are expected to perform design and safety analysis of the machines and structures in aerospace, automobiles, power plants, chemical plants, oil exploration, shipping, defense, civil applications etc.

Prerequisite :Mechanics of Solids

Sl No.	Article	No. of Classes
1	Overview and Application of Fracture Mechanics Approach to Engineering Design, Effect of Material Properties on Fracture, Failure, Combined Bending and Torsion, Historical Development, Contributions of Inglis, Griffith and Irwin, Classification of LEFM and EPFM, Modes of Loading: Mode-I, Mode-II and Mode-III, Photoelastic Fringes, Fatigue Crack Growth Model, Fracture Mechanisms: Brittle Fracture, Ductile Fracture, Fracture Mechanism in Metals and Non Metals, Void Nucleation and Growth, Ductile Brittle Transition.	06
2	Linear Elastic Fracture Mechanics (LEFM), Griffith Theory of Energy Balance, Energy Release Rate (G), Instability and R Curve, Stress Intensity Factor, (SIF) K, Relationship Between K and G, Crack-tip Stress and Displacement Field Equations, Airy's Stress Function for Mode-I, Westergaard Solution of Stress Field for Mode-I, Mode II, Mode III, Irwin's Model.	10
3	Elastic Plastic Fracture Mechanics (EPFM), Crack Tip Opening Displacement (CTOD), J Contour Integral, Relationship Between J and CTOD,J Controlled Fracture, Crack Growth Resistance Curves, HRR Field, Dynamic and Time Dependent Fracture, Creep Crack Growth (C* Integral), Viscoelastic Fracture Mechanics.	10
4	Fracture Toughness Testing of Metals, Specimen Configurations, Fatigue Precracking, K_{IC} Testing, K-R Curve Testing, J Testing, CTOD Testing, Dynamic and Crack Arrest Toughness, Fracture Testing of Non Metals, Plane Strain and Plane Stress Fracture Toughness Testing, Important Standards and Practices.	06
5.	Crack Initiation and Crack Growth, Paris Law, Crack Closure,Fatigue Threshold, K_{th} , K_{eff} .	04
6.	Computational Fracture Mechanics using ANSYS/ABAQUS/other softwares, Application of XFEM in Computational Fracture Mechanics.	03
	Total	**39**

Books recommended:

1. Fracture Mechanics - Fundamentals and Applications, 3rd Edition by T.L. Anderson, Taylor and Francis Group, 2005.
2. Elementary Engineering Fracture Mechanics, by D. Broek, Kluwer AcademicPublishers, Dordrecht, 4th revised Edition,1982.
3. Fracture Mechanics, by C.T. Sun, Z. –H. Jin, Academic Press,2nd Edition, 2006.
4. Elements of Fracture Mechanics by PrashantKumar,Tata McGraw Hill, New Delhi, India, 2009.
5. Fracture Mechanics for Modern Engineering Design, by K.R.Y. Simha.

(For 2 year M.Tech. Program in Applied Mechanics)

Specialisation: Mechanics of Solids / Mechanics of Fluids

2nd semester Paper-IX/X (DE)

Subject: **Nonlinear Dynamics and Chaos (AM5236)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

From the Newton's law of motion, it appears that, for the known initial conditions and the interacting forces, history of motion of a particle may be predicted forever into the future. It has, however, been uncovered now that such infinite predictability in dynamics may not be possible even for simple dynamical systems if they are essentially nonlinear in nature. In this background, the goal of this course is to introduce the ideas of nonlinear dynamics and standard mathematical approaches to explore problems of nonlinear dynamics and chaos that essentially exist in nature. Indeed, nonlinearity does exist in natural phenomena virtually covering every area of science and engineering. This course may thus be of significant interest to students of engineering and science even for inter-disciplinary research.

Expected Learning Outcomes for Course:

After successfully completing this course, students are expected to achieve:

(a) a newer insight into the subject 'Dynamics' far beyond the Newtonian Dynamics
(b) understanding on the predictability/unpredictability of various physical systems
(c) realization to different inter-disciplinary problems involving nonlinearity and
(d) renewed interest in the area of promising research.

Prerequisite: Fundamentals of Fluid Mechanics, Elementary Mathematics and Calculus

Serial No.	Article	No. of classes
01.	**Introduction:** Review of linear and non-linear vibration and introduction to bifurcations, Concepts of maps and flows, Overview of chaos and fractals.	**02**
02.	**1-D Dynamical Systems**: Fixed points, Stability, Bifurcations – Ideal and imperfect, Some canonical forms, A connection with physical problem.	**04**
03.	**2-D Dynamical Systems:** Phase plane, Fixed points and linear stability analysis, Limit cycles, Bifurcations revisited, Index theory, Examples from Newtonian dynamics.	**08**
04.	**Analytical Methods**: Averaging techniques, Perturbative methods, Duffing and Van der Pol oscillators.	**08**
05.	**Parametric Oscillators**: Introduction, Floquet theory, Mathieu equation, Linearly damped Mathieu equation.	**05**
06.	**Discrete Dynamical Systems**: Introduction, Bernoulli shift, Lyapunov exponent, Logistic map and Conjugate tent map, Routes to Chaos.	**06**
07.	**3-D Dynamical Systems:** Lorenz model, Geometry of strange attractor, Relation between dimension definitions and Lyapunov exponent, Fractal basin boundaries	**06**
	Total	**39**

Suggested Books:

1. Nonlinear Dynamics and Chaos by S. H. Strogatz, Westview
2. Nonlinear Oscillations by A.H. Nayfeh and D.T. Mook, Wiley, 1979
3. Nonlinear Oscillation in Physical Systems by C. Hayashi
4. Chaotic Vibrations: An Introduction for Applied Scientists and Engineers by F. C. Moon, Wiley

(For 2 year M.Tech Program in Engineering Mechanics)
Specialisation: Mechanics of Solid (MOS) / Mechanics of Fluids (MOF)
2nd Semester Paper-IX/X (**DE**)
Subject:**: Stochastic Structural Dynamics (AM5238)**

Contact Period: 3L per week Full Marks: 100, Pass Marks: 50 [Credit – 03]

Course objectives:

Engineering Systems are structures often experience dynamic loads that are random in nature e.g. the effect of wind gust on an aircraft wing or a wind turbine.

The main objectives of the course

- Introduce Mathematical techniques to describe randomness/uncertainty
- Introduce Monte Carlo Simulation techniques of studying the system responses under the effect of random dynamic loads.

Expected Learning Outcomes from the Course:

After successfully completing this course, students will:

- Learn to make an assessment of the responses of engineering structures, idealized as oscillators, which are subjected to random dynamic loads.

Prerequisite: Theory of Vibration

Sl No.	Article	No. of Classes
1.	**Random Variables:** Introduction to uncertainty, Introduction to Probability, Probability Space, Random Variables, Functions of Random Variables, Probability Distributions, Expectations, Commonly occurring random variables. Sequence of random variables and limit theorems.	11
2.	**Stochastic Processes:** Random processes and classifications, Stationary and ergodicity, Power spectral density function and auto -covariance functions, Gaussian, Poisson and Poisson pulse processes, Mean square derivatives and integrals.	9
3.	**Monte-Carlo Simulations**: Introduction, Simulation of Random Variables and Random Processes	5
4.	**Random Vibrations:** Random Vibration of a single-degree-of-freedom oscillator, Random Vibration of multi-degree-of-freedom oscillators, Non-linear systems, Uncertainty propagation under stationary and non-stationary excitations, Structural failure under random vibrations, Level crossing problems, First passage time, Models for peaks and envelopes, Extreme value distributions, Miscellaneous Topics: Karhunen-Louve Expansions, Polynomial Chaos	14
	Total	**39**

Books:

1. A. Papoulis (1997). Probability, random variables and stochastic processes, McGraw-Hill, NY.
2. Y.K. Lin (1967). Probabilistic theory of structural dynamics, McGraw-Hill, New York.
3. N.C. Nigam (1983). Introduction to random vibrations. MIT Press, Massachusetts.
4. L.D. Lutes, S. Sarkani (2004). Random vibrations: analysis of structural and mechanical systems, Elsevier.

(For 2 year M.Tech. Program in Applied Mechanics)

Specialisation: Mechanics of Solids

2^{nd} semester Paper-IX/X (DE)

Subject: **Micromechanics of Composites (AM5240)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

Provide general concepts of:

- Homogenization, micromechanical modelling of composites

Expected Learning Outcomes from the Course:

After successfully completing this course, students will:

- Understand the concepts of homogenization, representative volume element, effective properties of a heterogeneous medium, mechanics of architecture materials, mechanics of nanostructures

Prerequisite: Mechanics of Solids

Sl. No.	Article	No. of Classes
1.	Introduction and review of mathematical principles and continuum mechanics, Homogenization: Representative Volume Element Concept, Averaging schemes, Micromechanical homogenization theory, Eshelby's approach, Self-consistent model, Mori-Tanaka method	13
2.	Micromechanics of cellular, granular and porous materials	12
3.	Mechanics of nanostructures e.g., carbon nanotubes, graphene, polymer nanocomposites, Introduction to damage mechanics	9
4	Introduction to computational homogenization	5
Total		**39**

Books:

1. Metal Matrix Composites, N. Chawla and K.K. Chawla, Springer, 2nd edition, 2013
2. Micromechanics of composite materials, Jacob Aboudi, Steven M. Arnold, and Brett A. Bednarcyk, Elsevier, 2013
3. Micromechanics of Defects in Solids, T. Mura, Springer, 1987
4. Cellular Solid: Structure and Properties, L.J. Gibson and M.F. Ashby, Cambridge University Press, 2nd edition, 1997
5. A Course in Damage Mechanics, J. Lemaitre, Springer-Verlag, 1992

(For 2 year M. Tech Program in Applied Mechanics)
Specialization: Mechanics of Solids (MOS)
2nd semester Paper- IX/X (DE)
Subject: **Advanced Finite Element Method in Solid Mechanics (AM5242)**

Contact Period: 3L per week   Full Marks: 100, Pass Marks: 40 [Credit – 03]

Course objectives:

Knowledge in Finite element Method is now essential for designing and product development for Industry as well as in research. This course will help a student or scholar to use this finite element technique more efficiently.

This course has three objectives:

- Introduction to Different types of solution approach
- Provide theoretical knowledge to formulate different types elements and different types of nonlinearities.
- Provide knowledge regarding how to simulate industrial design problem using FE software

Expected Learning Outcomes for Course:

After successfully completing this course, the students will:

- Understand the different methods of solution approach of Finite element methods
- Understand the concepts of different types of element formulations
- Get confidence to develop the codes for different types finite element formulation
- Understand the formulation of different types nonlinearities and its physical significance. Get ideas regarding the heat transfer and mass transport problems

- Learn how to use a commercial finite element software efficiently

Prerequisite: Introductory knowledge in finite element method

Sl No.	Article	No. of Classes
1.	Differences in direct stiffness method and energy methods	3
2.	Axisymmetric and solid element formulation.	3
3.	Area coordinate methods,	2
4.	Pascal triangle, Lagrangian & Serendipity elements ,	3
5.	Shape functions & Higher order elements, Beam problem with the help of Rayleigh-Ritz method, Galarkin Method	5
6.	Isoparametric elements , Jacobian Matrix, Gauss quadrature, Numerical Integration,	5
7.	Introduction to different FE software and its use	3
8.	Different types of elements used in FE software	3
9.	Material nonlinearity, Large displacements, Visco elastic and Hyper elastic material modelling,	4

10.	Geometric nonlinearity	3
11	Formulation of heat transfer and Mass transport problems	5
Total		**39**

Books:

1. Finite element method D L Logan Cengage Learning
2. Concepts and Applications Of finite element Analysis RD Cook,D s malkus (Wiley)
3. finite element method Its basis & fundamentals by O C Zienkiewicz, R L Taylor

<u>**(For 2 year M.Tech Program in Applied Mechanics)**</u>

Specialisation: Mechanics of Fluids

2^{nd} semester paper- IX/X (DE)

Subject: **Parallel Computation in CFD (AM5244)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

Massive computations are necessary for large scale problems which can be obtained by parallel computation. This technique is often used in the simulation of fluid flow and structural mechanics.
The objective of this course is as follows,

- Teach the practical aspect of parallel computation
- Provide theoretical knowledge and practical knowledgeof CFD code parallelization;

Expected Learning Outcomes for Course:

After successfully completing this course, students will:

- Understand the structure of a parallel program.
- Understand the different parallel architectures, and programming models.
- Understand the different communication methodologies involved in parallelization.
- Given a problem, develop an efficient parallel algorithm to solve it.
- Hands on experience in parallelization of FVM based CFD solvers.

Prerequisite: Basics of CFD and Programming knowledge in any one of FORTRAN, C, and C++

Sl No.	Module name and Topics	No. of Classes
1.	**Introduction to parallel computation:** Needs for parallel computations. Challenges of parallel programming- Parallel Programming Paradigms – ParallelArchitecture - Overview of some parallel systems. Multiprocessors and multi-computers.	4
2.	**Modelling and analysis of parallel computations:** Efficiency characteristics of parallel computation: speedup, efficiency, scalability - Model analysis: determining the parallel method execution time, estimating the maximum possible parallelization, computational load balancing - The Amdahl's and Gustavson-Barsis's laws - Aggregating the computation model.	4
3.	**Parallel programming with MPI and communication:** Overview of the MPI standard. Point-to-point communication operations. Synchronous and asynchronous modes of data transmission. Collective operations. Derived data types. Process management. Logical topologies.	6
4.	**Application of parallel programming to CFD:** Basic structure – selection of communication operations - 1D wave equation - 1D Euler equation.	13
5.	**Parallelization of multi-dimensional CFD solvers :** Challenges in multi-dimensional problems – domain decomposition – communication models –Post processing	12
	Total	**39**

<u>**Books**</u>:

1. Grama, Ananth, et al. Introduction to parallel computing. Pearson Education, 2003.
2. Pacheco, Peter. An introduction to parallel programming. Elsevier, 2011.
3. Kirk, David B., and W. Hwu Wen-Mei. Programming massively parallel processors: a hands-on approach. Morgan kaufmann, 2016.
4. Schmidt, Bertil, et al. Parallel programming: concepts and practice. Morgan Kaufmann, 2017.

(For 2 year M.Tech. Program in Applied Mechanics)
Specialisation: Mechanics of Fluids
2nd semester Paper-IX/X (DE)
Subject: **Instrumentation in Fluid Mechanics** (**AM5246)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:
This is an open elective course which will deal with the details of various instruments as well as measurements of physical quantities related to fluid flow. The course will deal with both theoretical understanding and numerical problems of flow measurement, uncertainty, error analysis etc.

Expected Learning Outcomes for Course:
After successfully completing this course, students will:
(1) Understand the physics behind fluid flow visualisation and techniques
(2) Fundamentals of flow measurements and proper selection of instruments, range, uncertainty
(3) Learn computerized data acquisition
(4) Physics of optical measurements, measurement of flow field using PIV
(5) Intrusive and non-intrusive measurements

Prerequisite: Nil

Course outline:

Sl. No.	Article	No. of Classes
1	Introduction, Flow Properties and Basic Principles, Wind Tunnels and Water Tunnels	5
2	Flow visualization techniques, Introduction to measuring instruments Measurement Uncertainty	7
3	Measurement of Pressure and volume flow rate, velocity, Force Measurements, Temperature measurements, Hotwire Measurements	9
4	Data Acquisition, Processing and uncertainty analysis, Static and dynamic response of measuring systems	8
5	PIV Measurements, Integral optical measurement techniques: Shadowgraph, Schlieren & Interferometers, LDV Measurements	10
	Total	39

Books:

- **Tavoularis, S., Measurement in Fluid Mechanics, Cambridge University Press, 2005**
- R.J. Goldstein (Editor), 1996. Fluid Mechanics Measurements, 2nd Edition, Taylor and Francis, Washington.
- E. Rathakrishnan, 2007. Instrumentation, Measurements and Experiments in Fluids, CRC Press, Boca Raton, Florida.

(For 2 year M.Tech Program in Applied Mechanics)
Specialisation: Mechanics of Fluids

2nd Semester Paper-IX/X (DE)

Subject: **Microfluidics (AM5248)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:
This is one of the departmental elective subjects of the specialisation of Mechanics of Fluids - intended to cover the fundamentals of micro-scale transport processes, with emphasis on low Reynolds number flows and interfacial phenomena associated with small length scales. We discuss the governing equations for mass, momentum, energy and species balance. Specific attention is given to the theory of Electro-kinetics, surface tension driven flows, and species dispersion and separation over small length scales. Practical applications pertaining to each chapter/topic will be discussed in detail.

Expected Learning Outcomes for Course:
After successfully completing this course, students will:

• learn about the fundamentals of Micro-scale transport phenomena – both theory and relevant experimental methods.

• develop the ability of solving various engineering problems related to Microfluidics, using the analytic tools introduced in the course.

• learn about the real life applications of Microfluidics, and utilize the acquired knowledge in developing new technologies.

Prerequisite: Fluid Mechanics, Viscous Fluid Flow

Sl No.	Article	No. of Classes
1.	**Introduction to Microfluidics:** Advantages of miniaturization; Applications of microfluidics; Microfabrication techniques – Photolithography, Soft lithography, CNC-based manufacturing.	04
2.	**Governing equations, boundary conditions and some solutions of micro-scale transport processes:** Reynolds transport theorem, mass and momentum conservation, First law of thermodynamics, species conservation, entropy balance; Some exact solutions for low Reynolds number flow, oscillating flow, transient flow	13
3.	**Surface tension driven Capillary flow:** Interfacial Equilibrium, Young-Laplace equation; Lumped system approach; Dynamic contact angle	06
4.	**Electro-kinetics:** Electric Double Layer, Electro-osmotic flow, Joule heating in micro-channel, Streaming potential, Electrophoresis.	08
5.	**Dispersion in narrow channel:** Hydrodynamic dispersion in pressure driven flow, Taylor-Aris dispersion regime; Electro-kinetic dispersion; Chromatography; Species separation – Capillary electrophoresis, Free flow zone electrophoresis	08
	Total	**39**

Books:

1. Physiochemical Hydrodynamics *by* R F Probstein, John Wiley & Sons, Inc.
2. Viscous Fluid flow *by*F M White, McGraw-Hill, Inc.

(For 2 year M.Tech. Program in Applied Mechanics)

Open Elective

2nd semester Paper-IX/X (OE)

Subject: **Free Surface Flow (AM5263)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives: In recent years water-resources projects and hydraulic engineering works have been developing rapidly throughout the world.The knowledge of free surface flow which is essential to the design of many hydraulic structures has thus advanced by leaps and bounds. This course has the following objectives:

- To introduce basic principles, the types of flow in open channels classified according to the variation in the parameters of flow with respect to space and time, coefficients for velocity and pressure distributions.
- To provide knowledge about the energy and momentum principles constituted the basis of interpretation for most hydraulic phenomena.
- To introduce uniform flow, several uniform flow formulae, the design oferodible, nonerodible and grassed channels.
- To provide knowledge on gradually varied flow, several methods for the computation of flow profiles, new method of direct integration, the method of singular point which is a powerful tool for the analysis of flow profiles.
- To provide knowledge in rapidly varied flow involving hydraulic jump, its use as energy dissipater, its
control, flow over spillway analyzing and implementing the real engineering problems.

Expected Learning Outcomes for Course:

After successfully completing this course, students will:

•Understand how extensive use of free surface flow is made for different practical real problems related towater resources and hydraulic engineering works.

•Understand the modern numerical methods for solving the governing equations of different problems and also understand the solution of dam break problems both by numerical and simplified methods of computations. •Understand the treatment of rapidly varied flow problem largely supported by experimental data because this type of flow is so complicated that a mere theoretical analysis in most cases will not yield sufficient information for the purpose of practical design.

•Be able to design different channels like lined and unlined channel, stable channel, earthen channel and grass-lined channel considering both economic and seepage losses.

•Be able to have the ideas of flow through bridge contractions, the control of hydraulic jumps with sharp and broad-crested weirs, abrupt rises and drops, stilling basins, spillway structures and the design of channel transitions, the design, construction and use of physical models in the study of open channel hydraulics.

Prerequisite: Hydraulics and Fluid Mechanics

Sl No.	Article	No. of Classes
1.	Basic principles: velocity and pressure distribution, effects of slope and curvature on pressure distribution, application of energy and momentum principles.	06
2.	Uniform Flow: development of uniform flow and its formulas, computation of uniform flow, theoretical concepts of surface roughness, velocity distribution and instability of uniform flow, design of channels for uniform flow.	08

3.	Gradually Varied Flow: continuity and dynamic equations, analysis of flow profile, method of singular point, method of computation, backwater effect of a dam.	08
4.	Spatially Varied Flow: basic principles and assumptions, dynamic equation of spatially varied flow, analysis of flow profile, method of numerical integration.	09
5.	Rapidly Varied Flow: characteristics of flow, hydraulic jump and its use as energy dissipator, control of jump, stilling basin, flow over spillway.	08
	Total	39

Book: 1. Open Channel Hydraulics by VenTe Chow

2. Open Channel Hydraulics by Richard H. French

(For 2 year M.Tech Program in Applied Mechanics)

Open Elective

2nd semester paper- IX/X (OE)

Subject: **Parallel Computation for Engineers (AM5264)**

Contact Period: **3L per week**, Full Marks: **100**, Pass Marks: 40 [Credit – **03**]

Course objectives:

Massive computations are necessary for large scale problems which can be obtained by parallel computation. This technique is often used in the simulation of fluid flow and structural mechanics.

The objective of this course is as follows,

- Teach the practical aspect of parallel computation
- Provide theoretical knowledge and practical knowledgeof parallelization;

Expected Learning Outcomes for Course:

After successfully completing this course, students will:

- Understand the structure of a parallel program.
- Understand the different parallel architectures, and programming models.
- Understand the different communication methodologies involved in parallelization.
- Hands on experience in parallelization
- Basic Understanding about GPU parallelization

Prerequisite: Basic programming knowledge in any one of FORTRAN, C, and C++

Sl. No.	Module name and Topics	No. of Classes
1.	**Introduction to parallel computation:** Needs for parallel computations. Challenges of parallel programming- Parallel Programming Paradigms – ParallelArchitecture - Overview of some parallel systems. Multiprocessors and multi-computers.	5
2.	**Modelling and analysis of parallel computations:** Efficiency characteristics of parallel computation: speedup, efficiency, scalability - Model analysis: determining the parallel method execution time, estimating the maximum possible parallelization, computational load balancing - The Amdahl's and Gustavson-Barsis's laws - Aggregating the computation model.	5
3.	**Parallel programming with MPI and communication:** Overview of the MPI standard. Point-to-point communication operations. Synchronous and asynchronous modes of data transmission. Collective operations. Derived data types. Process management. Logical topologies.	8
4.	**Basics of GPU Programming:** Introduction to GPU Architecture - History, graphics processors, graphics processing units, GPGPUs. Clock speeds, CPU / GPU comparisons, heterogeneity. Accelerators, parallel programming, CUDA / OpenCL / OpenACC,	8
5.	**Case study on parallel programming:** Algorithm development – selection of communication operations - Case studies: matrix computations, solving partial differential equations –1D Wave Equation.	13
Total		**39**

Books:

5. Grama, Ananth, et al. Introduction to parallel computing. Pearson Education, 2003.
6. Pacheco, Peter. An introduction to parallel programming. Elsevier, 2011.
7. Kirk, David B., and W. Hwu Wen-Mei. Programming massively parallel processors: a hands-on approach. Morgan kaufmann, 2016.
8. Schmidt, Bertil, et al. Parallel programming: concepts and practice. Morgan Kaufmann, 2017.
9. Cai, Yiyu, and Simon See, eds. GPU computing and applications. Singapore: Springer, 2015.