Course Structure and Curriculum

Bachelor of Technology

in

Engineering and Computational Mechanics

(Effective from 2023-2024)

Applied Mechanics Department

Motilal Nehru National Institute of Technology Allahabad,

Prayagraj-211004

VISION AND MISSION OF THE INSTITUTE

VISION

To attain a distinct identity for the Institute through technology innovation, knowledge creation and dissemination for the benefit of the society.

MISSION

- To nurture an eco-system for continuous enhancement of value-based teaching and learning process in the emerging areas of technology.
- To train quality human and knowledge resources in the service of society.
- To develop sustainable products and technologies.

VISION AND MISSION OF THE DEPARTMENT

VISION

To be at the forefront of creation and dissemination of knowledge and technology in the multidisciplinary fields of Engineering Mechanics and Materials towards solving the challenges and needs of the discipline and the society.

MISSION

- To create and disseminate knowledge resource and sustainable technology through research and innovation in emerging Technological domains.
- To nurture value-based leaders in the Engineering Mechanics, Materials and allied areas capable of solving the challenges and needs of the discipline and the society.

Program Educational Objectives (PEOs)

The *Program Educational Objectives* (PEOs) embody the expected accomplishments of students, who successfully graduate from the program, during their first few years (about 3-5) following their graduation. The PEOs for the present program are as follows.

PEO-1	To develop the ability and confidence among the students for successful analysis and sustainable development of method/product in related industry / R&D organizations by means of successfully applying their knowledge on engineering and computational mechanics and its engineering applications, acquired during their graduation.
PEO-2	To inculcate the professional attitude, effective communication and leadership skills in the students to work as leading collaborators on multidisciplinary projects.
PEO-3	To provide the necessary background and motivation to the students for life-long and self-learning for their personal and professional growth following the professional ethics, environmental and social responsibility.
PEO-4	To inculcate into students, the qualities required to ignite thought process necessary for critical thinking and innovation in their work so as to enable them to successfully pursue advanced studies / research.

Mapping of *Program Educational Objectives* (PEOs) to *Mission Statements* (MS)

(Program Articulation Matrix)

Mission Statements	PEO-1	PEO-2	PEO-3	PEO-4
MS-1	3	2	3	3
MS-2	2	3	2	3

1-Slight; 2-Moderate; 3-Substantial

Graduate Attributes (GAs):

The following *Graduate Attributes* (GAs), attained through the *Program Outcomes* mentioned later, would help the successful students passing through the program to achieve the aforementioned PEOs.

1. **Scholarship of Knowledge**: Acquire in-depth knowledge of specific discipline or professional area, including wider and global perspective, with an ability to discriminate, evaluate, analyze and synthesize existing and new knowledge, and integration of the same for enhancement of knowledge.
2. **Critical Thinking**: Analyse complex engineering problems critically, apply independent judgment for synthesizing information to make intellectual and/or creative advances for conducting research in a wider theoretical, practical and policy context.
3. **Problem Solving**: Think laterally and originally, conceptualize and solve engineering problems, evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions after considering public health and safety, cultural, societal and environmental factors in the core areas of expertise.
4. **Research Skill**: Extract information pertinent to unfamiliar problems through literature survey and experiments, apply appropriate research methodologies, techniques and tools, design, conduct experiments, analyze and interpret data, demonstrate higher order skill and view things in a broader perspective, contribute individually/in group(s) to the development of scientific/technological knowledge in one or more domains of engineering.
5. **Usage of modern tools**: Create, select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and Modeling, to complex engineering activities with an understanding of the limitations.
6. **Collaborative and Multidisciplinary work**: Possess knowledge and understanding of group dynamics, recognize opportunities and contribute positively to collaborative-multidisciplinary scientific research, demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis in order to achieve common goals and further the learning of themselves as well as others.
7. **Project Management and Finance**: Demonstrate knowledge and understanding of engineering and management principles and apply the same to one's own work, as a member and leader in a team, manage projects efficiently in respective disciplines and multidisciplinary environments after consideration of economic and financial factors.
8. **Communication Skill**: Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.

9. **Life-long Learning**: Recognize the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.
10. **Ethical Practices, Environment and Social Responsibility**: Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.
11. **Independent and Reflective Learning**: Observe and examine critically the outcomes of one's actions and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

Mapping of *Graduate Attributes* (GAs) to *Program Educational Objectives* (PEOs)

PEOs	GA-1	GA-2	GA-3	GA-4	GA-5	GA-6	GA-7	GA-8	GA-9	GA-10	GA-11
PEO-1	√	√	√	√	√					√	
PEO-2	√	√	√	√	√	√	√	√			
PEO-3	√	√	√						√	√	√
PEO-4	√	√	√	√	√	√		√	√		√

PROGRAM OUTCOMES (POs):

PO-01	Engineering Knowledge: Apply knowledge of mathematics and computing, science, engineering mechanics fundamentals to the solution of complex engineering problems
PO-02	Problem Analysis: Identify, formulate and analyse complex problems to reach to proper conclusions using first principles of mathematics, natural sciences and engineering sciences.
PO-03	Design/Development of Solutions: Design solutions for complex mechanics based problems and design/develop the processes/software/components which meets specified needs and standards keeping in mind the health, safety, cultural, societal and environmental conditions.
PO-04	Conduct investigations: Conduct investigations of complex engineering problems using research-based knowledge and methods using data analysis and interpretation for provide valid conclusions.
PO-05	Modern Tool Usage: To apply appropriate techniques, resources and engineering and IT tools and knowledge for modelling and simulation of engineering problems with an understanding of the limitations.
PO-06	The Engineer and Society: Apply contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice.
PO-07	Environment and Sustainability: Understand the impact of professional Engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development.
PO-08	Ethics: Apply ethical principles and commit to professional ethics responsibilities and norms of Engineering practice.
PO-09	Individual and Team Work: Function effectively as an individual, and as a member or leader in diverse teams as well as in multi-disciplinary settings.
PO-10	Communication: Communicate effectively with the engineering community and with society at large and being able to comprehend and make effective reports/documents and effective presentation.
PO-11	Project Management and Finance: Demonstrate knowledge and understanding of management principles and apply these to one's own work, as a member and leader of a team, to manage projects and in multidisciplinary environments.

PO-12	Life-long Learning: Recognize the need for the preparation and ability to engage in independent and life- long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

PSO-01	Graduates will be able to apply fundamental knowledge of mathematics, science and engineering mechanics to investigate, identify, formulate and design complex problems in the engineering and computational mechanics and allied multidisciplinary areas.
PSO-02	Graduates will be able to develop and apply the appropriate techniques and modern engineering tools to solve complex real-life problems by working with multi-disciplinary team and inculcate skills for life-long and self-learning.

Mapping of *Program Outcomes* (POs) to *Program Educational Objectives* (PEOs)

POs	PEO-1	PEO-2	PEO-3	PEO-4
PO-1	3	3	2	2
PO-2	3	3	1	1
PO-3	3	3	3	1
PO-4	2	2	1	1
PO-5	2	1	1	1
PO-6	1	3	1	1
PO-7	2	2	1	1
PO-8	1	1	3	2
PO-9	1	3	2	1
PO-10	1	1	3	1
PO-11	2	2	1	3
PO-12	1	1	2	2
PSO-1	3	2	1	1
PSO-2	1	1	3	2

1-Slight; 2-Moderate; 3-Substantial

Course Structure and Detailed Curriculum

Semester wise Credit Distribution									
Semester	I	II	III	IV	V	VI	VII	VIII	**Total**
Credits	23	23	26	26	22	22	15	14	**161**

Semester I							
Code	**Category**	**Course Name**	**L**	**T**	**P**	**C**	**Hrs.**
CYN11502/ XXXXXX	CEF	Engineering Chemistry -II/Physics-1	2	1	2	**4**	5
MAN11101	CEF	Mathematics-I	3	1	0	**4**	4
HSN11600/CSN11601	PCE	Professional Communication/Introduction to Artificial Intelligence and Machine Learning	2	0	2	**3**	4
AMN11101	CEE	Materials Science and Engineering	3	0	0	**3**	3
AMN11102	CEE	Engineering Mechanics	3	0	2	**4**	5
CHN11102	CEE	Engineering Thermodynamics	3	0	0	**3**	3
XXXXXX	EAA	Extra Academic Activity-A/B	0	0	4	**2**	4
		Total	**16**	**2**	**10**	**23**	**28**

Semester II							
Code	**Category**	**Course Name**	**L**	**T**	**P**	**C**	**Hrs.**
XXXXXX /PHN12501	CEF	Engineering Chemistry -II/Physics-1	2	1	2	**4**	5
MAN12107	CEF	Mathematics-II	3	1	0	**4**	4
HSN12600/CSN12601	PCE	Professional Communication/Introduction to Artificial Intelligence and Machine Learning	2	0	2	**3**	4
CSN12401/ XXXXXX	CES	Data structures/Introduction to Simulation Tools/Engineering Innovation and Design/Introduction to Engineering and Design	2	0	2	**3**	4
AMN12102	CEE	Fluid Mechanics	3	0	0	**3**	3
MEN12102	PCE	Engineering Graphics	1	0	2	**2**	3
CHN12400	PCE	Environment and Climate Change	2	0	0	**2**	2
EAN12700-12705	EAA	Extra Academic Activity-A/B	0	0	4	**2**	4
		Total:	**15**	**2**	**12**	**23**	29
Extra Academic Activity-A: Professional Ethics and Social Values							
Extra Academic Activity-B: (Options) Yoga, Language, Health, Multimedia, Sports and other available choices							

Semester III							
Code	**Category**	**Course Name**	**L**	**T**	**P**	**C**	**Hrs.**
MAN13103	CEE	Linear Algebra and Discrete Mathematics	4	0	0	**4**	4
AMN13107	CEE	Mechanics of Solids	3	0	0	**3**	3
AMN13108	CEE	Biology for Engineers	3	0	0	**3**	3
AMN13109	CEE	Thermo-Fluids Engineering	3	0	2	**4**	5
AMN13105	CEE	Data Sciences and Machine Learning in Mechanics	3	0	2	**4**	5
AMN13110	CEE	Engineering Analysis and Design	3	0	0	**3**	3
XXXXXX	HSS	Management Concepts and Application/Business Economics	3	0	0	**3**	3
XXXXXX	EAA	Extra Academic Activity-B*	0	0	4	**2**	4
		Total:	**22**	**0**	**4**	**26**	**30**

Semester IV							
Code	**Category**	**Course Name**	**L**	**T**	**P**	**C**	**Hrs.**
AMN14102	CEE	Applied Mathematics and Computation	3	0	2	**4**	5
XXXXXX	CEE	Analysis of Algorithms	3	0	2	**4**	5
		OR MOOC/SWAYAM course #					
AMN14105	CEE	Advanced Mechanics of Solids	3	0	2	**4**	5
AMN14106	CEE	Advanced Fluid Mechanics	3	0	0	**3**	3
AMN14107	CEE	Biomechanics	3	0	0	**3**	3
AMN14108	CEE	Dynamics of Mechanical Systems	3	0	0	**3**	3
XXXXXX	HSS	Management Concepts and Application/Business Economics	3	0	0	**3**	3
XXXXXX	EAA	Extra Academic Activity-B*	0	0	4	**2**	4
		Total:	**21**	**0**	**10**	**26**	**31**

Semester V							
Code	**Category**	**Course Name**	**L**	**T**	**P**	**C**	**Hrs.**
AMN15102	CEE	Continuum Mechanics and Constitutive Modeling	4	0	0	**4**	4
AMN15103	CEE	Finite Element Methods	3	0	2	**4**	5
AMN15300	CEE	Tinkering Lab	0	0	6	**3**	6
AMN15104	CEE	Compressible Flow and Computations	3	0	0	**3**	3
AMN15105	CEE	Design and Analysis of Experiments	3	0	0	**3**	3
XXXXXX	CEL	Core Elective-I	3	0	0	**3**	3
XXXXXX	EAA	Extra Academic Activity-B*	0	0	4	**2**	4
		Total:	**16**	**0**	**10**	**22**	**28**

Semester VI							
Code	**Category**	**Course Name**	**L**	**T**	**P**	**C**	**Hrs.**
AMN16351	CEE	Group Project	0	0	6	**3**	6
AMN16101	CEE	Computational Fluid Dynamics	3	0	2	**4**	5
AMN16102	CEE	Mathematics for Geometrical Modeling	3	0	2	**4**	5
AMN16103	CEE	Engineering Vibrations	3	0	0	**3**	3
XXXXXX	CEL	Core Elective-II OR	3	0	0	**3**	3
XXXXXX		MOOC/SWAYAM course#					
XXXXXX	HSS	Soft Skill and Personality Development	2	0	1	**3**	3
XXXXXX	EAA	Extra Academic Activity-B*	0	0	4	2	4
		Total:	**14**	**0**	**15**	**22**	**29**

Semester VII							
Code	**Category**	**Course Name**	**L**	**T**	**P**	**C**	**Hrs.**
AMN17352	CEE	Group Project/Research Project	0	0	6	**3**	6
AMN17101	CEE	Digital Image Processing	3	0	2	**4**	5
XXXXXX	CEL	Core Elective-III	3	0	0	**3**	3
XXXXXX	CEL	Core Elective-IV/MOOC/SWAYAM course#	3	0	0	**3**	3
XXXXXX	EAA	Extra Academic Activity-B*	0	0	4	**2**	4
		Total:	9	0	12	**15**	21

* Optional Courses: Yoga, Language, Health, Multimedia, Sports and other available choices

Computer Graphics/Data Mining/Artificial Intelligence/Database Management Systems/High Performance computing/Parallel Computing/Quantum Computing

	Semester VIII						
Code	**Category**	**Course Name**	**L**	**T**	**P**	**C**	**Hrs.**
AMN18353	IT/GP	Industrial Training/Major Project	0	0	28	**14**	28
		Total	0	0	28	**14**	28
	Elective-I & II (V & VI Semester, ONE in each)						
	CEL	Optimization-I	3	0	0	**3**	3
	CEL	Mechanical Behaviour of Materials	3	0	0	**3**	3
	CEL	Aerodynamics	3	0	0	**3**	3
	CEL	Mechanical System Design	3	0	0	**3**	3
	CEL	Structural Mechanics	3	0	0	**3**	3
	Elective-III & IV (VII Semester, Any two)						
	CEL	Optimization-II	3	0	0	**3**	3
	CEL	Soft Robotics	3	0	0	**3**	3
	CEL	Characterization of Materials	3	0	0	**3**	3
	CEL	Product Design and Development	3	0	0	**3**	3
	CEL	Bio-Fluid Dynamics	3	0	0	**3**	3
	Honors (4-5 subjects)						
	CEL	Advanced Bio-Mechanics	4	0	0	**4**	4
	CEL	Biomimetics	4	0	0	**4**	4
	CEL	Poromechanics	4	0	0	**4**	4
	CEL	Mechanics of Composite Materials	4	0	0	**4**	4
	CEL	Multiscale Modeling	4	0	0	**4**	4
	CEL	Structural Reliability	4	0	0	**4**	4
	CEL	Structural Stability and Dynamics	4	0	0	**4**	4
	CEL	Advanced Heat Transfer	4	0	0	**4**	4
	CEL	Boundary Layer Theory	4	0	0	**4**	4
	CEL	Turbulent Flows	4	0	0	**4**	4
	CEL	Advanced Computational Fluid Dynamics	4	0	0	**4**	4

Course Code: AMN11101	Materials Science and Engineering	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: NIL

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	Understand role of structure at different level on properties.	1, 2	Remember, Understand
CO2	Apply concepts of Materials Science to analyze engineering problems.	3, 4	Apply, Analyze
CO3	Select materials for different engineering applications.	3	Apply
CO4	Predict the mechanical, thermal, electrical, magnetic, piezoelectric and other important properties.	3, 4	Apply, Analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	-	1	1	1	-	1	-	2	2	2	3	3
CO2	3	3	2	2	3	1	-	1	2	2	1	2	3	3
CO3	3	3	3	3	3	2	2	2	2	2	1	2	3	3
CO4	2	3	2	1	-	-	-	-	2	1	1	1	3	3

Module	Syllabus	Hours
1	**Introduction:** Historical perspective of Materials Science; Structure and properties relationship of Engineering Materials; Classification of materials; Introduction to Ceramics, Composites Materials: Processing and Applications; Advanced Materials.	05
2	**Structure of Solids and Characterization of Materials:** Introduction to crystal structures and systems; Metallic structures; Ceramic crystal structures; Crystallographic directions and planes, Miller indices, Density computations, Crystallography, Diffraction methods, Metallography, Introduction to Electron microscopy and Thermal characterization techniques.	07
3	**Imperfections in Crystals:** Types of imperfections, Dislocations, Surface and Bulk defects	03
4	**Diffusion:** Diffusion mechanisms, steady and non-steady state diffusion, Factors that influence diffusion, Law's of diffusion, Applications of Diffusion.	03
5	**Phase Diagrams and Phase Transformations:** Unary, Binary, Equilibrium phase diagrams, Eutectic, Eutectoid, Peritectic and peritectoid reactions, Transformation rate effects and TTT diagrams. Microstructure and property changes in iron-carbon system, Iron-Carbon (Fe-C or Fe-Fe3C) Diagram.	05
6	**Mechanical Behaviour of Materials:** Elastic and Plastic properties, Fatigue, Fracture, Creep.	10
7	**Thermal, Electrical, Magnetic, Optical Properties:** Thermal behaviour of Materials; Electrical conduction, Semi conductivity, Super conductivity, Dielectric behaviour, Ferroelectricity, Piezoelectricity, Magnetic behaviour of Materials; Optical properties of materials and their applications	07

References

- "Materials Science and Engineering: An Introduction" by William D. Callister Jr., David G. Rethwisch.
- "Materials Science and Engineering: A First Course" by Raghavan V.
- "Mechanical Metallurgy" by George E. Dieter
- "Elements of materials science and engineering" by Lawrence H. Van Vlack.

Course Code: AMN11102	Engineering Mechanics	Credits (L-T-P-Cr): 3-0-2-4

Pre-requisites: None

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Identify and quantify all the external forces associated with the rigid body with the help of free body diagrams, their resultant and its location and use of equations of equilibrium.	2, 3	Understand, Apply
CO2	To locate the centroid of an area and calculate the moment of inertia of a section and assessment of the internal forces in beams	2, 3	Understand, Apply
CO3	Apply Newtons laws of motion to particles and rigid bodies.	3, 4	Apply/Analyze
CO4	Solve the problems involving kinematics, energy and momentum and write simple programs for problems of real life.	5	Evaluate

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	3	3	-	-	-	-	-	-	-	3	3
CO2	3	3	3	3	3	-	-	-	-	-	-	-	3	3
CO3	3	3	3	3	3	-	-	-	-	-	-	-	3	3
CO4	3	3	3	3	3	2	-	-	2	2	-	-	3	3

Module	Syllabus	Hours
1	Review of Force, moment and Couple, Equilibrium of rigid bodies, Centroid and Moment of inertia, Beams - Shear force, and Bending moment diagrams.	**15**
2	Kinematics and Kinetics of particles: Plane and Space motion, Force, Mass and Acceleration, Work & Energy, Impulse & Momentum, Impact, and Central Force Motion. Kinetics of system of particles: Conservation of Energy and Momentum, Steady mass flow, Variable mass.	**10**
3	Plane Kinematics and Kinetics of a rigid body: Relative velocity and Acceleration, Instantaneous centre of zero velocity, Rotating axis, Force, Mass and Acceleration, Work & Energy, Impulse & Momentum.	**12**
4	Introduction to three-dimensional kinematics and kinetics of rigid bodies.	**03**

Experiments on parallel and concurrent forces, sliding friction, rolling resistance, moment of inertia, SFD/BMD and programming for static and dynamic problems

References

- Meriam J.L., Kraige L.G and Bolton J.N., Engineering Mechanics Statics and Dynamics, 9ed (An Indian Adaptation), Wiley India.
- Beer F.P. and Johnston E.R., Mechanics for Engineers – Vol.1- Statics, Vol.2- Dynamics, McGraw Hill, New York.
- Shames I.H., Engineering Mechanics, Prentice Hall, New Delhi.
- Hibbeler R.C., Engineering Mechanics - Vol.1 –Statics, Vol.2- Dynamics, Pearson Press.

Course Code: AMN12102	Fluid Mechanics	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Engineering Mechanics, Mathematics-I

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	To give fundamental knowledge of fluid, its properties, hydrostatic laws and application of mass, momentum and energy equation in fluid flow.	2	Understand
CO2	To develop understanding about Dimensional Analysis, different types of flows and losses in a flow system.	2	Understand
CO3	To learn the importance of flow measurements and its applications in Industries.	3	Apply
CO4	To develop basic knowledge of hydraulic machines and its applications.	3, 4	Apply /Analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	1	1	1	-	-	-	-	-	-	2	3	3
CO2	3	2	1	1	2	-	-	-	-	-	-	1	3	3
CO3	-	-	2	-	2	-	-	-	-	-	-	-	3	3
CO4	3	3	2	-	-	-	-	-	-	-	-	2	3	3

Module	Syllabus	Hours
1	**Introduction to Fluid Mechanics:** Statics and Kinematics Fluid and continuum, Physical properties of fluids, Types of fluid flows, Rheology of fluids. Manometers, pressure transducers, pressure on plane and curved surfaces, centre of pressure, Kinematics of Fluid flow: steadiness, uniformity, rotational and irrotational flows, streamline, streakline, pathline, continuity equation, stream function and velocity potential, applications of potential flow.	**08**
2	**Dynamics Of Fluid Flow and Dimensional Analysis:** Euler's Equation of motion along a streamline and its integration, Bernoulli's equation and its applications, momentum equation and its application to pipe bends. Dimensional Analysis, Buckingham's Pi theorem, important dimensionless numbers and their physical significance, geometric, kinematic and dynamic similarity, model studies, Hydraulic similitude.	**08**
3	**Laminar and Turbulent Flows:** Equation of motion for laminar flow through pipes, Stokes law, transition from laminar to turbulent flow, types of turbulent flow, isotropic and homogenous turbulence, scale and intensity of turbulence, eddy viscosity, Prandtl's mixing length theory, velocity distribution in turbulent flow over smooth and rough surfaces, resistance to flow, minor losses, pipe in series and parallel, power transmission through a pipe, three reservoir problems and pipe network.	**10**
4	**Hydrodynamic Boundary Layer:** Introduction with a historical background, boundary layer, displacement and momentum thickness, boundary layer over a flat plate, Prandtl boundary layer equation, laminar boundary layer, application of momentum equation, turbulent boundary layer, laminar sub-layer, separation and its control, drag and lift, drag on a sphere, 2D cylinder and aerofoil, Magnus effect.	**08**
5	**Measurement Techniques & Introduction to Hydraulic Machines**: Flow measurement by Pitot tube, orifice, Venturi, nozzle, and bend meter, rotameter, Introduction to Hydroelectric power station and its components, Classification of turbines and pumps, similarity laws and specific speed, efficiency, cavitation.	**06**

References

- Munson, Young and Okiishi's Fundamentals of Fluid Mechanics, 9e by Philip M. Gerhart, Andrew L. Gerhart, John I. Hochstein, Wiley.
- Fox, R.W., McDonald, A.T., Introduction to Fluid Mechanics, 7th edition, Wiley India.
- Som, S.K. and Biswas G, Introduction of Fluid Mechanics & Fluid Machines, TMH, New Delhi. •
- Mohanty, A.K., Fluid Mechanics, PHI Learning, New Delhi.
- Shames, I.H., Mechanics of Fluids, McGraw Hill, International Students Edition.
- Agarwal, S.K., Fluid Mechanics and Machinery, TMH, New Delhi.
- Rathakrishnan E., Instrumentation, Measurements and Experiments in Fluids, CRC Press, New York
- Jagdish Lal, Fluid Mechanics, Metropolitan Book Company Ltd., Delhi.

Course Code: MAN13103	Linear Algebra and Discrete Mathematics			Credits (L-T-P-Cr) : 4-0-0-4
Pre-requisites: Mathematics-I, II				

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Understand the basic concepts of linear algebra, such as vector spaces, basis, dimension, linear transformation, solvability of a system of linear equations, etc.	2	Understand
CO2	Understand the basic concepts like eigenvalues, eigenvector, quadratic form, and diagonalization, and its application to solve engineering problems.	2, 3	Understand, Apply
CO3	The understand and apply the concepts of mathematical logic, recurrence relations and Boolean algebra	2, 3	Understand, Apply
CO4	Understand the simple concepts of Graph theory.	2	Understand

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	1	-	-	2	-	1	1	3	3	3
CO2	3	3	3	1	1	-	-	-	-	1	1	3	3	3
CO3	3	3	3	1	1	1	1	-	-	1	-	3	3	3
CO4	3	3	3	1	1	1	2	2	1	2	3	3	3	3

Module	Syllabus	Hours
1	**Linear Algebra:** Group, Ring, Field, Vector spaces, Subspaces, Linear dependence and independence, Basis and dimension, Dimension theorem.	7
2	**Eigenvalues and Eigenvectors:** Linear Transformation, Rank–Nulity Theorem (Statement only), Computation of Rank and nullity of LT, Eigenvalues and Eigenvectors, Cayley-Hamilton theorem, Application of Eigenvalues and Eigenvectors: Quadratic form, Diagonalization, Canonical forms.	9
3	**Mathematical Logic:** Statements, Connectives, Statement Variables and Formulas, Tautologies, Equivalences and Implications, Disjunctive and Conjunctive Normal Forms, Inference Theory in Statement Logic, Indirect Proofs.	7
4	**Combinatorics:** Permutations and Combinations, Permutations and Combinations with repetitions Ordered and Unordered Partitions, Sterling Numbers of First and Second Kind, Partition Functions, Linear Recurrence Relations (Difference Equations), Solution by Characteristic Roots, Generating Functions.	9
5	**Lattices and Boolean Algebra:** Boolean Matrices, Boolean Product, Partially Ordered Sets, Lattices, Modular and Distributive Lattices, Complements, Boolean Algebra, Stone Representation Theorem for Finite Boolean Algebras, Boolean Functions, Free Boolean Algebras, Relationship with Statement Logic.	9
6	**Introduction to Graph Theory:** Fundamental concepts of graphs and digraphs, Tree and their properties, Binary tree, spanning tree, connectivity, optimal graph traversals, Planarity of Graphs, Drawing graphs and maps, Graph colouring.	10

References

- R.K. Jain & S.R.K. Iyenger, Advanced Engineering Mathematics, 5th edition, 2016, Narosa Pub.
- B.S. Grewal, Higher Engineering Mathematics, 44nd edition, 2018, Khanna Publishers.
- D.B.West, Introduction to Graph Theory, Prentice-Hall of India/Pearson
- J.A. Bondy and U.S.R.Murty, Graph Theory and Applications (Freely downloadable from Bondy's website; Google-Bondy)
- Tremblay and Manohar, Discrete Mathematical Structures.
- Kolman, Busby and Ross, Discrete Mathematical Structures
- Mott, Kandel and Baker, Discrete Mathematical Structures
- Erwin Kreyszig, Advanced Engineering Mathematics, 10th Edition, 2015, John Wiley & Sons.
- Qazi Zameeruddin & Surjeet Singh, Modern Algebra, 9th edition 2021, S Chand Publication

Course Code: AMN13107	Mechanics of Solids	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Engineering Mechanics

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	Understand the concept of internal forces and moments, stress, strain, deformations in members subjected to axial, bending and torsional loads	2	Understand
CO2	Comprehend the concepts of principal stresses and strain to solve the problems of engineering elasticity	2	Understand
CO3	Apply the concepts to calculate stress, strain, and displacements in engineering structure and components such as beams, shaft, shells and springs	3	Apply
CO4	Analyse the mechanical engineering structures and components for safer mechanical design by considering appropriate failure criteria and design requirements.	4	Analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	1	-	-	2	-	1	1	3	3	3
CO2	3	3	3	1	1	-	-	-	-	1	1	3	3	3
CO3	3	3	3	1	1	-	-	-	-	1	1	3	3	3

Module	Syllabus	Hours
1	**Stress and Strain:** Uniaxial Stress and Strain, Hooke's Law, Stress-Strain Curves, Elastic Constants, Strain Energy, Statically Indeterminate Problems, Thermal Effects, Impact Loading.	**6**
2	**Biaxial Stress and Strain:** Stress at a Point, Stress Transformation, Analysis of Strain, Strain-Displacement Relations, Strain Transformation, Strain Measurements, Principal Stresses and Strain	**8**
3	**Bending and Shear Stresses:** Pure Bending, Normal Stress and Shear Stresses in beams, Composite Beams, Asymmetric Bending	**6**
4	**Torsion of Shaft, Springs, and Pressure Vessels:** Torsion of Circular Shaft, Power Transmitted by a Shaft, Compound Shaft, Combined Loadings, Thin-Walled Shells, and Springs (Open and Closed Coils)	**6**
5	**Deflections of Beams:** Equation of Elastic Curve, Methods for Determining Deflections: Double Integration, Macaulay's Method, Moment-Area Method, Castigliano's Theorem	**8**
6	**Columns and Theories of Failure**: Euler's Theory for Long Columns, Rankine-Gordon Formula, Eccentrically Loaded Columns, Theories of failure	**6**

References

- Mechanics of Materials, Gere and Timoshenko, CBS Publications.
- Introduction to Mechanics of Solids, Crandall, Dahl and Lardener, Tata Mcgraw Hill Publications.
- Mechanics of materials, Hibbert, R.C., 2005, Pearson Education.
- Elements of Strength of Materials, S.P. Timoshenko and D.H. Young, East-West Press Pvt. Ltd. Publications.
- Mechanics of Materials, Pytel and Kiusalaas, Cengage Learning Publications.
- Mechanics of Materials, E. P. Popov, Prentics Hall Publications.
- Strength of Materials, G. H. Ryder, Macmillan India Limited.
- Strength of Materials, Pytel and Singer, Harpercollins College division publications.
- Mechanics of Materials, Riley, Struges and Morris, John Wiley & Sons.

Course Code: AMN13108	Biology for Engineers	Credits (L-T-P-Cr): 3-0-0-3

Pre-requisites: NIL

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	To demonstrate a comprehensive understanding of the principles of human physiology and their application to engineering, allowing them to integrate physiological knowledge into engineering concepts and designs.	2, 4	Understand, Analyse
CO2	To analyze and explain the interrelationships between different physiological systems enabling them to identify and address engineering challenges in these areas.	2, 3	Understand, Apply
CO3	To develop the necessary skills to apply physiological knowledge to engineering innovations and applications in healthcare	2, 4, 5	Understand, Analyse, Evaluation
CO4	To effectively collaborate in interdisciplinary teams, to communicate and exchange ideas with professionals from different fields, and apply knowledge to real-world projects, innovation, and ethical awareness in the pursuit of healthcare and biomedical engineering.	2, 4, 5	Understand, Analyse, Evaluation

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	1	-	-	2	-	1	1	3	3	3
CO2	3	3	3	1	1	-	-	-	-	1	1	3	3	3
CO3	3	2	2	1	1	-	1	1	-	1	-	1	2	2
CO4	2	3	3	2	1	2	2	2	2	1	2	1	2	2

Module	Syllabus	Hours
1	**Cell:** Structure and organelles - Functions of each component in the cell. Cell membrane – transport across membrane – Origin of cell membrane potential – Action potential. Homeostasis - Tissue: Types – Specialized tissues – functions. **Blood:** Blood composition - functions of blood – functions of RBC.WBC types and their functions Blood groups – importance of blood groups – identification of blood groups.	**8**
2	**Musculoskeletal System** – Skeletal Anatomy, Bone Composition, Bone Tissue Architecture, Bone Adaptation and Remodelling, Bone Disorders, Muscle Tissue, Structure of Skeletal Muscle, Types of Muscle, Types of Joints, Major Muscles of Limbs, and their actions.	**8**
3	**Cardiovascular system**– Heart and vascular system, Lymphatic System ECG – Blood Pressure – Homeostasis –Cardiac output – Coronary and Peripheral Circulation – Heart Sounds. Bohr effect, Applied aspects, Ventilators, Oxygen Therapy.	**6**
4	**Respiratory system:** Components of respiratory system – Respiratory Mechanism. Types of respiration - Oxygen and carbon dioxide transport and acid base regulation. Pulmonary function test – Artificial respiration – Cardio-pulmonary Resuscitation	**6**
5	**Gastro urinal system -** Digestion, and absorption – Movement of GI tract, Structure and function of kidneys and Nephron – Mechanism of Urine formation – Urine Reflex – Skin and Sweat Gland – Temperature regulation.	**5**
6	**Nervous System** – Structure and functions of Neurons, Synapse, Reflex action, and Receptors – Velocity of Conduction of Nerve Impulses – Nervous control of Heart.	**5**

References

- Essential of Human Anatomy and Physiology by Elaine.N. Marieb, Pearson Education, 11th Edition.
- The Human Body: An introduction for Biomedical and Health Sciences by Gillian Pocock, Christopher D. Richards, Oxford University Press, USA
- Introduction to the human body: the essentials of anatomy and physiology by Gerard J Tortora and Bryan Derrickson, John Wiley & Sons, 8th Edition.
- Physiology for Engineers: Applying Engineering Methods to Physiological Systems by Michael Chappell and Stephen Payne, Springer, Biosystems & Biorobotics Volume 13.

Course Code: AMN13109	Thermo-Fluids Engineering	Credits (L-T-P-Cr) : 3-0-2-4

Pre-requisites: Fluid Mechanics, Thermodynamics

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	To identify thermodynamic systems, surroundings, work and heat interaction using fluids and their characteristics in various thermodynamic processes.	2	Understand
CO2	To identify and apply modes of heat transfer related to fluids and surface interaction e.g., conduction and convection.	3, 4	Analyze / Apply
CO3	To understand the concepts of thermodynamic laws and Entropy.	2	Understand

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	1	1	1	-	-	-	-	-	-	2	3	3
CO2	3	3	3	1	2	-	-	-	-	-	-	1	3	3
CO3	-	3	1	-	1	-	-	-	-	-	-	-	3	3

Module	Syllabus	Hours
1	**Basic Equations and Steady State Conduction:** General three-dimensional heat conduction equation, Steady one-dimensional heat conduction through simple and composite planes, cylindrical and spherical walls without heat generation, Effect of variable thermal conductivity, Critical thickness of insulation. Steady one-dimensional heat conduction through plane wall, hollow cylinder, solid cylinder and solid sphere with uniform heat generation, Heat transfer from finned surfaces, general equation, efficiency and effectiveness of fins, conduction in cooling of turbine balding, optimum dimensions, comparison of fin materials. Two-dimensional steady state heat conduction, Numerical and graphical methods, Analogical solution.	**10**
2	**Unsteady State Heat Conduction:** Heating and Cooling with negligible internal resistance, Temperature-time response of thermocouple, Heating and cooling with negligible surface resistance, Transient heat conduction in semi-infinite solids, Laplace's equation, Separation of Variables, Lumped capacitance methods, Heating and Cooling of infinite plate with finite internal and surface resistance, Numerical and graphical analysis	**08**
3	**Convection:** Laminar and turbulent flow, hydrodynamic and thermal boundary layer. Dimensional analysis and dimensionless numbers for free and forced convection. Empirical relations and practical solution of free and forced convection in pipes, over plates and across cylinders and spheres, combined free and forced convection, combined free convection and radiation heat transfer.	**10**
4	**Thermodynamic Laws and Entropy:** Reversibility and irreversibility, statements of second law and their discussion, Equivalence of Kelvin-Planck and Clausius statements, Carnot engine and Carnot refrigeration, Thermodynamic temperature scale and absolute zero temperature, Clausius theorem and Clausius inequality, concept and characteristics of entropy Principle of increase of entropy and entropy of universe.	**08**

Experiments related to fluid mechanics and thermo-fluids along with programming on advanced problems

References

- Introduction to Thermodynamics, Classical and Statistical, Third Edition, Sonntag, R.E., and Van Wylen, G, John Wiley and Sons, 1991.
- Advanced Engineering Thermodynamics, Bejan, A., John Wiley and Sons, 1988.
- Advanced Thermodynamics for Engineers, Kenneth Wark Jr., McGraw-Hill Inc., 1995.
- Fundamentals of Heat & Mass Transfer, Incropera F.P. and DeWitt. D.P., John Wiley & Sons, 1996.
- Analysis of Heat and Mass Transfer, Ozisik. M.N., McGraw Hill Co., 1980.
- Heat Transfer - Basic Approach, Eckert. E.R.G., and Drake.R.M., McGrawHill Co., 1985.
- Convection Heat Transfer, Bejan. A., John Wiley and Sons, 1984.

Course Code: AMN13105	Data Sciences and Machine Learning in Mechanics	Credits (L-T-P-Cr) : 3-0-2-4

Pre-requisites: Mathematics, Introductory Computer Programming

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	To demonstrate understanding of the mathematical foundations and programming skills needed for data science and machine learning	2, 3	Understand, Apply
CO2	To understand and analyze all possible models available in Machine learning	2, 4	Understand, Analyze
CO3	To be able to apply the Machine Learning for analyzing various practical application related to Mechanics	3	Apply

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	1	2	3	-	-	-	-	-	-	3	3	3
CO2	3	3	2	1	3	-	-	-	-	-	-	3	3	3
CO3	3	3	3	3	3	1	1	1	1	1	1	3	3	3

Module	Syllabus	Hours
1	Introduction to Data Science: Concept of Data Science, Traits of Big data, Web Scraping, Analysis vs Reporting	4
2	Introduction to Programming Tools for Data Science: Toolkits using Python- Matplotlib, NumPy, Scikit-learn, NLTK, Visualizing Data- Bar Charts, Line Charts, Scatterplots, working with data- Reading Files, Scraping the Web, Using APIs (Example: Using the Twitter APIs), Cleaning and Munging, Manipulating Data, Rescaling, Dimensionality Reduction, Introduction to RStudio	6
3	Mathematical Foundations: Linear Algebra- Vectors, Matrices; Statistics- Describing a Single Set of Data, Correlation, Simpson's Paradox, Correlation and Causation; Probability- Dependence and Independence, Conditional Probability, Bayes's Theorem, Random Variables, Continuous Distributions, The Normal Distribution, The Central Limit Theorem; Hypothesis and Inference- Statistical Hypothesis Testing, Confidence Intervals, Phacking, Bayesian Inference	4
4	Machine Learning: Overview of Machine learning concepts – Over fitting and train/test splits, Types of Machine learning – Supervised, Unsupervised, Reinforced learning, Introduction to Bayes Theorem, Linear Regression- model assumptions, regularization (lasso, ridge, elastic net), Classification and Regression algorithms- Naïve Bayes, K-Nearest Neighbors, logistic regression, support vector machines (SVM), decision trees, and random forest, Classification Errors, Analysis of Time Series- Linear Systems Analysis, Nonlinear Dynamics, Rule Induction, Neural Networks Learning And Generalization	16
5	Applications of Machine Learning in Mechanics: Case Studies include Identifying faulty/healthy wind turbines, Turbulent Flow Analysis, Leakage Detection in Hydraulic Circuits, Fault Detection in Motor-Bearings, Human Activity Recognition, Heart Sound Classification etc.	4
6	Deep learning: Introduction to Neural Networks, Convolution and Artificial Neural Networks, Applications in Engineering Mechanics Practical's: MATLAB tools including Curve Fitting Toolbox, Classification Learner App, Deep Network Designer App, Tensor Flow, Training models on GPUs	6

Programming in the Python for predicting specific outcomes and application to the mechanics based problems in failure/fault analysis

References

- Sud, Keshav, Pakize Erdogmus, and Seifedine Kadry, eds. *Introduction to Data Science and Machine Learning*. BoD–Books on Demand, 2020.
- Kroese, Dirk P., Zdravko Botev, Thomas Taimre, and Radislav Vaisman. *Data science and machine learning: Mathematical and statistical methods*. CRC Press, 2019.
- Cielen, Davy, and Arno Meysman. *Introducing data science: big data, machine learning, and more, using Python tools*. Simon and Schuster, 2016

Course Code: AMN13110	Engineering Analysis and Design	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Materials Science and Engineering, Mechanics of Solids

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	To Identify and analyze different modes of failures in materials	2, 4	Understand, Analyze
CO2	To develop understanding of different design approaches in general and some methods used in design	2, 3	Understand/Apply
CO3	To develop skill of material selection for the specific task based on different design criteria	4	Analyze
CO4	To evaluate the material's performance with reference to the cost, societal health and safety	5	Evaluate

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	2	3	1	-	-	-	-	-	-	-	3	2
CO2	2	2	3	1	3	-	-	-	-	-	-	-	3	2
CO3	2	1	3	2	1	3	3	2	-	-	3	2	3	3
CO4	1	2	2	3	3	1	2	-	1	1	3	3	2	3

Module	Syllabus	Hours
1	**Analysis:** Common causes and mechanism of failure, principles and techniques of failure analysis, fracture mechanics approach to failure problems, ductile and brittle fracture, fracture toughness, elements of design for fatigue, Cyclic Stresses and the S–N Curve, crack initiation and propagation, fatigue failure models, measuring and estimating fatigue failure criteria, high temperature failure and creep, stress and temperature effects, wear failure, design failures, processing failure (forging, casting, machining etc.), failure problems in joints and welds	15
2	**Design Philosophies:** Introduction to Uncertainties with examples relevant to different disciplines in science and engineering, Traditional design philosophies: factor of safety approach, partial safety factor approaches. Probability and statistics as tools for uncertainty quantification. Stochastic models for loads and structure capacities.	10
3	**Methods:** Modern Design Cycle, Need Analysis and Broad Engineering Specifications, Concept Design, Feasibility study and Evaluation of alternatives, Engineering Economics, Modeling Techniques-Mathematical, Graphical, Analysis and Simulation (e.g., FEM, Monte Carlo, CFD, Dimensional analysis, Experimental Techniques), Design for Manufacture and Reliability, Sustainability and Environment, Safety, Ergonomics and Human Factors, Introduction to design sensitivity analysis, life prediction.	7
4	**Basics of Materials selection:** strength, stiffness, and fatigue life consideration, materials indices, the selection strategy and procedure, multiple constraints and conflicting objectives, Selection of materials and shape: shape factors, limits to shape efficiency, exploring the materials shape combinations, materials indices that include shape	8

References

- Practical Stress Analysis in Engineering Design, Ronald Hudson and Harold Josephs, CRC press
- Engineering Materials 1: An Introduction to Properties, Applications and Design, MF Ashby, DRH Jones, Elsevier (Butterworth-Heinemann)
- Probabilistic model code (2000). Joint Committee on Structural Safety.
- HO Madsen, S Krenk, NC Lind (1986). Methods of structural safety. Prentice Hall, NJ.
- Machine Design, An integrated approach, Robert L. Norton, Prentice Hall
- Machine Elements: Life and Design, BM Klebanov, DM Balram and FE Nystrom, CRC press
- Materials and Design, The Art and Science of Material Selection in Product Design, Mike Ashby and Kara Johnson, Elsevier (Butterworth-Heinemann)
- Materials Selection in Mechanical Design, MF Ashby, Elsevier

Course Code: AMN14105	Advanced Mechanics of Solids	Credits (L-T-P-Cr) : 3-0-2-4

Pre-requisites: Mechanics of Solids

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Understand the concept of tensor	2, 4	Understand, Analyze
CO2	Analyze advanced concept of stress and strain in structural problems.	2, 3	Understand, Apply
CO3	Apply the concept of different elastic functions to solve complex problems	3	Apply
CO4	Evaluate the influence of various geometric and loading parameters in plane stress and plane strain problems	5	Evaluate

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	1	-	-	2	-	1	1	3	3	3
CO2	3	3	3	1	1	-	-	-	-	1	1	3	3	3
CO3	3	3	3	1	1	1	1	-	-	1	-	3	3	3
CO4	3	3	3	1	1	1	2	2	1	2	3	3	3	3

Module	Syllabus	Hours
1	**Mathematical Preliminaries:** Introduction to tensor algebra: symmetric and skew-symmetric tensor, summation convention, eigenvalue and eigenvector of tensor, spectral theorem, polar decomposition theorem, product of tensor, principal invariants of tensor, coordinate transformation of tensor, Tensor calculus: gradient, divergence, curl, differentiation of scalar function of a tensor.	**08**
2	**Analysis of Stress and Strain:** Definition and notation of stress, Cauchy stress tensor, equations of equilibrium, principal stresses and stress invariants, stress deviator tensor, octahedral stress components, General deformations, small deformation theory, strain transformation, principal strains, spherical and deviatoric strains, Strain-displacement relations, strain compatibility, Generalized Hooke‟s law, Strain-energy, stress and strain in curvilinear, cylindrical, and spherical coordinates, fundamental equations of plasticity.	**16**
3	**Problem formulation and solution strategies:** Field equations, boundary conditions, stress and displacement formulation, Beltrami-Michell compatibility equations, Lame-Navier’s equations, principle of superposition, uniqueness theorem, Saint-Venant’s principle, Brief descriptions about general solution strategies - direct, inverse, semi-inverse, analytical, approximate, and numerical methods.	**12**
4	**Two-dimensional problems:** Plane stress and plane strain problems, generalized plane stress, Antiplane strain, Airy stress function, polar coordinate formulation and solutions, Cartesian coordinate solutions using polynomials and Fourier series method.	**04**

Experiments related to tensile, compression, torsion and shear tests, bending of beams, buckling of columns and MATLAB programming to solve the basic and advanced problems

References

- Theory of Elasticity by M. Filonenko-Borodich
- Advanced Mechanics of Solids by L.S.Srinath
- Theory of Elasticity by S.P. Timoshenko and J. N. Goodier,
- Elasticity, Theory, Applications, and Numerics by Martin H. Sadd
- Advanced Mechanics of Solids by Otto T. Bruhns
- Continuum Mechanics by A.J.M Spencer
- Advanced Mechanics of Materials by H. Ford and J. M. Alexander
- The Linearized Theory of Elasticity by W. S. Slaughter

Course Code: AMN14106	Advanced Fluid Mechanics	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Fluid Mechanics

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	An ability to apply basic governing laws and potential flow theory to solve problems in fluids engineering.	2,3	Understand / Apply
CO2	An ability to identify Boundary layer separation, its causes and control.	2	Understand
CO3	An ability to apply the concepts developed for fluid flow analysis in aerospace and other applicable areas	3, 4	Apply /Analyze
CO4	To understand the basic aspects of different type of compressible flows and shocks		

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	1	1	1	-	-	-	-	-	-	2	3	3
CO2	3	3	3	1	2	-	-	-	-	-	-	1	3	2
CO3	2	3	2	2	2	-	-	-	-	-	-	-	3	3
CO4	3	3	-	1	1	-	-	-	-	-	-	-	3	1

Module	Syllabus	Hours
1	**Basic Conservation & Governing Laws:** Statistical & continuum methods, Eulerian &Lagrangian coordinates, material derivatives, control volumes, Reynolds' transport theorem (RTT), conservation of mass, momentum and energy, constitutive equations, Navier-Stokes equations differential & integral approach, energy equations, governing equations for Newtonian fluids, boundary conditions.	**08**
2	**Potential Flows:** Stokes stream functions, solution of potential equation, flow in a sector, flow around a sharp edge, flow near a blunt nose force and moment on a circular cylinder and sphere, conformal transformations, Joukowski transformations.	**08**
3	**Viscous Incompressible Flows:** Exact solutions for Couette flow, Poiseuille flow, flow between rotating cylinders, Stokes' first problem, Stokes' second problem, pulsating flow between parallel surfaces, stagnation point flow, flow in convergent and divergent channels, flow over porous wall. Stokes approximation, rotating sphere in a fluid, uniform flow past a sphere and cylinder, Ossen's approximation, Hele-Shaw flow.	**10**
4	**Introduction to Boundary Layer:** Derivation of boundary layer equation, how potential flow complements B.L. equation, Integral solution of B.L., Laminar and turbulent boundary layers; transition; B.L. separation and control.	**08**
5	**Introduction to Compressible Flow:** Velocity of sound and its importance, physical difference between incompressible, subsonic and supersonic flows, Mach number and its significance. Isentropic flow through nozzles, shocks and expansion waves, Rayleigh and Fanno Flow.	**06**

References

1. "Fundamental Mechanics of Fluids", I. G. Currie.
2. "Foundations of Fluid Mechanics", S.W. Yuan, Prentice-Hall India Pvt. Ltd, New Delhi.
3. "Advanced Fluid Mechanics", K. Muralidhar & G. Biswas, Narosa Publishing, 2005.
4. "Boundary Layer Theory", H. Schlichting, 6th Edition, McGraw-Hill Inc., 1986.
5. "Modern Compressible Flow with Historical Perspective", John D. Anderson, McGraw Hill.
6. "Fundamentals of Aerodynamics" (2nd ed), J. D. Anderson, McGraw Hill.
7. "Fundamentals of Fluid Mechanics", B.R. Munson, D.F. Young & T.H. Okiishi, 2nd Ed., John Wiley.
8. "Introduction to Fluid Mechanics", R.W. Fox & A.T. McDonald, 5th Edition, John Wiley, 2001.
9. "Viscous Fluid Flow", F. M. White, 2nd Edition, McGraw-Hill, 1991

Course Code: AMN14102	Applied Mathematics and Computation	Credits (L-T-P-Cr) : 3-0-2-4

Pre-requisites: Mathematics and Programming skills

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	To Identify the differences between "Exact methods & Computational Methods" and applications of these methods.	2, 4	Understand, Analyze
CO2	To Develop knowledge of expressing a real-life problem in terms of mathematics i.e., to develop the skill of Mathematical Modelling.	2, 3	Understand, Apply
CO3	To Identify and develop the skill to solve real life engineering problems e.g. Nonlinear Problems, Initial Value & Boundary Value Problems, Numerical Differentiation & Integration problems.	3	Apply
CO4	To develop skill of writing Flow Charts of real-life engineering problems and transform those into computer programming	5	Evaluate

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	-	-	-	-	-	-	-	1	3	3
CO2	3	3	3	1	-	-	-	-	-	-	-	2	3	3
CO3	3	3	3	1	-	-	-	-	-	-	-	1	3	3
CO4	3	3	3	1	3	-	-	-	1	-	-	3	3	3

Module	Syllabus	Hours
1	**Review of Elementary Engineering Mathematics:** Error and its propagation, Solution of homogeneous and non-homogeneous equations; Power series.	**3**
2	**Linear Algebra:** Matrices and Linear Transformations, Operational Fundamentals of Linear Algebra, Systems of Linear Equations, Gauss Elimination Family of Methods, Special Systems and Special Methods, Numerical Aspects in Linear Systems, Eigenvalues and Eigenvectors, Diagonalization and Similarity Transformations, Jacobi and Givens Rotation Methods, Tri-diagonal Matrices, QR Decomposition Method, Eigenvalue Problem of General Matrices, Singular Value Decomposition, Direct and Iterative solvers.	**8**
3	**Ordinary Differential Equations:** Introduction to ordinary differential equations, homogeneous linear equations of second order, non-homogeneous linear equations of second order, free and forced oscillation problems, problems with variable coefficients, system of equations.	**5**
4	**Partial Differential Equations (PDEs):** Existence and uniqueness of differential equations, nature of solution, Hyperbolic, Parabolic and Elliptic PDEs, nonlinear PDEs.	**5**
5	**Nonlinear Equations:** Motivation, Open and bracketing method, Bisection, Fixed point, Newton's method, Secant and False position method, Rate of convergence, Merits and demerits of methods.	**4**
6	**Numerical Integration:** Motivation, Newton-Kotes method, Trapezoidal rule, Simpson's rule, Rhomberg integration, Gauss Quadrature.	**4**
7	**Initial Value Problem:** Motivation, Euler's method, Modified Euler method, Runge-Kutta methods, Adaptive integrations and multistep methods.	**4**
8	**Boundary-value and Eigen-value Problem:** Methods and Applications in Mechanics.	**2**
9	**Statistical Computations**: Frequency Chart, Regression Analysis, Least Square fit, Polynomial fit, Linear and Nonlinear Regression, Multiple Regression, Statistical Quality Control Methods.	**5**

Programming on MATLAB/Excel and other platforms such as C++/Python to solve the problems

References

- S. C. Chapra and R. P. Canale, Numerical Methods for Engineers.
- R. W. Hamming, Numerical Methods for Scientists and Engineers (Dover Books on Mathematics).
- Amos Gilat, Numerical Methods for Engineers and Scientists.
- K.E. Atkinson, An Introduction to Numerical Analysis.
- G. E. Golub and C.F. Van Loan, Matrix Computations.

Course Code: AMN14107	Biomechanics	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: NIL

Course Objectives: To impart knowledge about:

1. Mechanics principles which can be applied to human structure and function.
2. Kinetic and kinematics concepts for analysing human movements.
3. Physiological behaviour of body tissue

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	To understand basic concepts of mechanics for kinetics and kinematic analysis of human motion.	2	Understand
CO2	To comprehend and describe the nature of loading in musculoskeletal system	2	Understand
CO3	To conceptualize the basic principles of tissue biomechanics of bone, cartilage, ligament and muscle.	2	Understand
CO4	To apply the knowledge in biomechanical applications such as implant design and sports biomechanics	3, 4	Apply, analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	1	1	-	-	-	2	1	1	3	2
CO2	3	3	3	2	1	2	-	-	-	2	1	1	2	3
CO3	3	2	2	2	1	1	-	-	-	2	1	1	2	2
CO4	3	2	2	2	2	3	1	1	1	2	2	2	3	3

Module	Syllabus	Hours
1	**Human Movement:** Anatomical concepts to describe Human Movement, Kinematics: Jumping, Walking, Running, Gait Analysis, Kinetics: Kinetic Variables, interpretation of kinetic data	8
2	**Muscle Mechanics:** Skeletal muscle morphology and physiology, muscle constitutive modeling, whole muscle mechanics, muscle/bone interactions	6
3	**Skeletal Biomechanics:** Composition and structure of bone, biomechanical properties of bone, bone fractures, adaptation and remodelling, mechanobiology	6
4	**Cellular and Tissue Biomechanics:** Cellular biomechanics: cytoskeletons, cell-matrix interaction, methods to measure the mechanical properties of cell and biomolecules, structure of collagen, ligament, tendon and cartilage, biomechanical properties of ligament, tendon, and cartilage,	8
5	**Implant Design and Computational Biomechanics:** Bone-implant system, implant material, fracture fixation device, joint replacement, design of bone implant system, total hip replacement, total knee replacement, articulating surface, computational modeling in biomechanics	8

References

- Susan J Hall, “Basics of Biomechanics’’, Mc Graw Hill Publishing.co. New York, 9th Edition, 2022.
- Y. C. Fung, —Bio-Mechanics, “Mechanical Properties of Tissues”, Springer-Verilog,1998.
- C. Ross Ether and Craig A. Simmons, “Introductory Biomechanics from cells to organisms”, Cambridge University Press, New Delhi, 2009
- D. L. Bartel, T. Davy Dwight, and Keaveny Tony M. "Orthopaedic biomechanics-Mechanics and design in musculoskeletal systems”, Upper Saddle River, New Jersey: Peardson Prentice Hall. 2006.
- Hamill, J., & Knutzen, K. M. “Biomechanical basis of human movement”, Lippincott Williams & Wilkins. 2006.

Course Code: AMN14108	Dynamics of Mechanical Systems	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Engineering Mechanics, Mathematics

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Understand the basics of variational calculus and energy methods	2, 4	Understand, Analyze
CO2	Analyze advanced concept of dynamics using Lagrangian dynamics and multi-body dynamics	2, 3	Understand, Apply
CO3	Apply the different concept of dynamics to solve complex problems	3	Apply
CO4	Evaluate the different parameters that influence the dynamics of cams, gears, rotating & reciprocating masses a and vibrations of the real structures	5	Evaluate

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	-	-	-	-	-	-	-	1	3	3
CO2	3	3	3	1	-	-	-	-	-	-	-	2	3	3
CO3	3	3	3	1	-	-	-	-	-	-	-	1	3	3
CO4	3	3	3	1	3	-	-	-	1	-	-	3	3	3

Module	Syllabus	Hours
1	**Basic concepts**: Introduction to Variational Calculus, Virtual work and Generalized forces, Energy methods	6
2	**Lagrangian dynamics:** Degrees of freedom, generalized coordinates and generalized forces, holonomic and non-holonomic constraints, Kane's equations, Lagrange's equations, Lagrange's equation from d'Alembert's principles, application of Lagrange's equation for conservative and non-conservative autonomous systems with holonomic and non-holonomic constraints, applications to systems with very small displacements and impulsive motion; Hamilton principle from d'Alembert's principle, Lagrange equation from Hamilton's principle.	10
3	**Multi-body dynamics:** Space and fixed body coordinate systems, coordinate transformation matrix, direction cosines, Euler angles, Euler parameters, finite and infinitesimal rotations, time derivatives of transformations matrices, angular velocity and acceleration vectors, equations of motion of multi-body system, Newton-Euler equations, planer kinematic and dynamic analysis, kinematic revolute joints, joint reaction forces, simple applications of planer systems.	12
4	**Cams and Gears, Balancing of rotating and reciprocating masses, Introduction to Vibrations**.	12

References

- Dynamics of Mechanical Systems, Harold Josephs and Ronald Huston, CRC Press.2002
- Energy principles and Variational methods in Applied Mechanics, JN Reddy, John Wiley and Sons
- Kinematics and Dynamics of Machinery, R. L. Norton, McGraw Hill
- Kinematics, Dynamics and Design of Machinery, K.J. Waldron and G. L. Kinzel, Wiley
- Advanced Engineering Dynamics, Ginsberg, J.H., Harper and Row. 1988
- Methods of Analytical Dynamics, Meirovitch, L., McGraw Hill Inc. 1970
- System Dynamics, Katsuhiko Ogata, 4th Ed., Prentice Hall; 2003
- Modeling and Simulation of Dynamic Systems, Robert L. Woods and Kent L. Lawrence, Prentice Hall. 1997
- Modeling and Analysis of Dynamic Systems, 6 Ramin S. Esfandiari and Bei Lu, CRC Press 2010
- Principles of Analytical System Dynamics, Richard A. Layton, Springer

Course Code: MAN……….	Analysis of Algorithms	Credits (L-T-P-Cr) : 3-0-2-4

Pre-requisites: Data Structures and Discrete Mathematics

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	To understand fundamental algorithms for solving a variety of problems	2	Understand,
CO2	To Apply basic algorithms e.g., sorting, searching, divide and-conquer, dynamic programming, greediness, and probabilistic approaches	3	Apply
CO3	To analyze time and space complexity of algorithms and to evaluate tradeoffs between different algorithms	4, 5	Analyze/ Evaluate
CO4	To develop efficient algorithms, emphasizing methods useful in practice	6	Create

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	1	1	-	-	-	-	1	1	-	3	1
CO2	3	3	3	1	1	-	-	-	-	1	1	1	3	2
CO3	3	3	3	3	1	1	-	-	-	1	3	1	3	3
CO4	3	3	3	3	3	1	-	-	1	2	3	3	3	3

Module	Syllabus	Hours
1	Introduction, Review of basic concepts, Advanced data structures like Binomial Heaps, Fibonacci Heaps	**6**
2	Divide and conquer with examples such as Sorting, Matrix Multiplication, Convex hull etc	**6**
3	Dynamic programming with examples such as Kanpsack, All pair shortest paths etc	**6**
4	Backtracking, Branch and Bound with examples such as Travelling Salesman Problem etc	**8**
5	Algorithms involving Computational Geometry	**6**
6	Selected topics such as NP-completeness, Approximation algorithms, Randomized algorithms, String matching	**6**

References

- Fundamentals of Computer Algorithms by E. Horowitz & S Sahni
- The Design and Analysis of Computer Algorithms by Aho, Hopcraft, Ullman
- Introduction to Algorithms by Thomas H. Coreman, Charles E. Leiserson and Ronald L. Rivest

Course Code: AMN15103	Finite Element Methods	Credits (L-T-P-Cr) : 3-0-2-4

Pre-requisites: Mechanics of solids, Fluid Mechanics, Applied Mathematics and Computation

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Identify the primary and derived dependent variables involved, kinematic and natural constrains	2	Understand
CO2	Formulate, through use of energy principles and Variational methods, relevant finite element equations and implement the same into computer program	3, 4	Apply, Analyze
CO3	Analyze, interpret and communicate results obtained from developed computer program as well as from commercial finite element Software	4, 5	Analyze, Evaluate
CO4	Use of commercial FEA software and in-house development of solvers/codes	6	Create

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	1	-	-	2	-	1	1	3	3	3
CO2	3	3	3	1	1	-	-	-	-	1	1	3	3	3
CO3	3	3	3	1	1	1	1	-	-	1	-	3	3	3
CO4	3	3	3	1	1	1	2	2	1	2	3	3	3	3

Module	Syllabus	Hours
1	**Basic Concepts:** Introduction, Weak formulations, Weighted residual methods, Variational formulations, weighted residual, collocation, subdomain, least square and Galerkin's method, direct method, potential energy method	08
2	**One-Dimensional Analysis:** Basis steps, discretization, element equations, linear and quadratic shape functions, assembly, local and global stiffness matrix and its properties, boundary conditions, applications to solid mechanics, heat and fluid mechanics problems, axisymmetric problems, **Plane Truss:** Local and global coordinate systems, stress calculations, example problems **Beams:** Introduction, Euler-Bernoulli beam element, numerical problems	12
3	**Scalar Field Problems in 2-D:** Triangular and rectangular elements, constant strain triangle, isoparametric formulation, higher order elements, six node triangle, nine node quadrilateral, master elements, numerical integration, computer implementation, Numerical problems	10
4	**Plane Elasticity:** Review of equations of elasticity, stress-strain and strain-displacement relations, plane stress and plane strain problems **Bending of Elastic Plates:** Review of classical plate theory, plate bending elements, triangular and rectangular elements, Shear deformation plate theory, numerical problems.	10

Application through Computer Programming: Input for Geometric & Material Configuration, Loading and Boundary Conditions, Automatic Mesh Generation, Nodal Coordinate and Nodal Connectivity, Calculation of Element Matrices (Stiffness & Mass Matrices, Load Vector), Assembly of Element Matrices to Global Matrices, Imposing Boundary Conditions, Solution (Gauss Elimination & other methods), Post Processing.

References

- Energy and Finite Element Methods in Structural Mechanics: I. H. Shames and C. L. Dym.
- Concepts and Applications of Finite Element Analysis: R. D. Cook, D. S. Malkus and M. E. Plesha.
- The Finite Element Method Vol. I-II: O.C. Zienkiwiczand R.L. Taylor.
- Finite Element Procedures: K. J. Bathe.
- An Introduction to Finite Element Methods: J.N. Reddy.
- Finite Element Methods in Engineering: S.S. Rao.

Course Code: AMN15104	Compressible Flow and Computations	Credits (L-T-P-Cr) : 3-0-0-3
Pre-requisites: Applied Mathematics and Computation, Advanced Fluid Mechanics, Introductory Gas Dynamics		

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Understand and apply the fundamentals of numerical simulation in the real-life compressible flow problems	2,3	Understand / Apply
CO2	Comprehensively understand the governing equations pertinent to the compressible flows and their solution techniques	2,3	Understand / Apply
CO3	Analyze the underlying complex flow physics of the compressible flows.	4	Analyze
CO4	Facilitate in developing the in-house codes.	4	Analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	-	1	1	-	-	-	-	-	-	2	3	3
CO2	3	3	3	1	2	-	-	-	-	-	-	1	3	3
CO3	-	3	3	3	2	-	-	-	-	-	-	-	3	3
CO4	1	1	3	3	3	3	3	-	-	-	-	2	3	3

Module	Syllabus	Hours
1	**Governing Equations & Riemann problem and its solution:** Basic governing equations (Euler equation and Navier-StokesFourier equations) and relations(Calorically perfect gas, Sutherland formula) describing the compressible flows, Method of characteristics and the solution of linear hyperbolic equations, Riemann problem for linear system of equations and its solution, Riemann problem for Euler equations and its solution.	08
2	**Grid generation techniques:** C-,H-,O- grid topologies, Structured grid (algebraic, elliptic, hyperbolic), unstructured grid (Delaunay triangulation, advancing-front method), mixed element/hybrid grids, grid smoothening, grid adaptation	08
3	**Spatial discretization based on finite volume method:** Cell-centred and cell-vertex schemes, Convective fluxes (advection upwind splitting schemes, Roe's approximate Riemann solver, total variation diminishing (TVD) scheme, piecewise liner reconstruction, Green-Gauss approach, least-square approach), Limiter functions (minmod, Harten, TVD, superbee) , Viscous fluxes (central difference, Green's theorem, elements based gradients, average of gradients)	10
4	**Temporal Discretization:** Explicit time stepping schemes (Runge-Kutta multistage scheme, hybrid-multistage scheme, treatment of source term, Courant-Fridreichs-Lewy (CFL) condition)), Implicit time stepping schemes (alternating direction implicit (ADI), lower-upper symmetric Gauss-Siedel (LU-SGS)), dual time stepping schemes for unsteady flows	08
5	**Development of numerical codes:** One dimensional Euler solver, structured and unstructured two-dimensional Eulerand Navier-Stokes solvers, Compressible flow solver based on the limiter approach, Development of Euler and Navier-Stokes multicomponent compressible flow solver in both Cartesian and Curvilinear approach. Function of the limiter at high shock strength.	06

References

- "Physics of Shock Waves and High Temperature Hydrodynamic Phenomena", Y. B. Zel'dovich , Yu P. Raizer.
- "Numerical Computation of Internal and External Flows, Volume 2", Charles Hirsch.
- "Riemann Solvers and Numerical Methods for Fluid Dynamics", E. F. Toro.
- "Introduction to Compressible Fluid Flow", Oosthuizen Patrick H.
- "Modern Compressible Flow with Historical Perspective", John D. Anderson, McGraw Hill.

Course Code: AMN15102	Continuum Mechanics and Constitutive Modelling	Credits (L-T-P-Cr) : 4-0-0-4

Pre-requisites: Advanced Solid Mechanics

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Make use of the concepts of tensor formalism for practical applications	2, 4	Understand, Analyse
CO2	Identify stresses acting on components subjected to complex loads	2, 3	Understand, Apply
CO3	Apply deformation and strain concepts for practical situations	3	Apply
CO4	Develop constitutive relations and solve 2 D elasticity problems	6	Evaluate

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	1	-	-	2	-	1	1	3	3	3
CO2	3	3	3	1	1	-	-	-	-	1	1	3	3	3
CO3	3	3	3	1	1	1	1	-	-	1	-	3	3	3
CO4	3	3	3	1	1	1	2	2	1	2	3	3	3	3

Module	Syllabus	Hours
1	**Mathematical Preliminaries and Introduction:** Index notation, range and summation convention, free and dummy indices, Kronecker delta, Levi-Civita symbol, co-ordinate transformations, Cartesian tensor, properties of tensors, tensors as linear operators, invariants of tensor, eigen values and Eigen vectors, polar decomposition, scalar, vector and tensor functions, comma notation, gradient of a scalar, gradient of a vector, divergence and curl of a tensor, integral theorems of vectors and tensors. Notion of a continuum, configuration, mass and density, descriptions of motion, material and spatial coordinates.	08
2	**Kinematics of Deformation and Motion:** Deformation gradient tensor, stretch and rotation, right and left Cauchy-Green deformation tensors, Eulerian and Lagrangian strain tensors, strain-displacement relations, infinitesimal strain tensor, infinitesimal stretch and rotation, compatibility conditions, principal strains and strain deviator, material and local time derivatives, stretching and vorticity, path lines, stream lines, vortex lines, Reynolds transport theorem, circulation and vorticity.	10
3	**Forces and Stresses:** Body and surface forces, Cauchy Stress Tensor, First and Second Piola-Kirchhoff Stress Tensor, Deviatoric and Pressure Components, Principal Stress.	6
4	**Fundamental Balance Laws of Continuum Mechanics:** Balance of Mass – Continuity Equation; Balance of Linear Momentum – Equations of Motion / Equilibrium Equations; Moments of Momentum (Angular Momentum); Balance of Energy - First Law of Thermodynamics, Energy Equation; Equations of State – Entropy, Second Law of Thermodynamics; Clausius-Duhem Inequality, Dissipation Functions	8
1.	**Constitutive Relations and Material Models:** Constitutive Assumptions; Ideal Fluids; Elastic Fluids, Hyperelastic Material; Notion of Isotropy; Isothermal Elasticity - Thermodynamic Restrictions, Material Frame Indifference, Material Symmetry; Hooke's law, Stokes problem and Newtonian fluids.	

References

- Introduction to the Mechanics of a Continuous Medium: Lawrence E. Malvern.
- An Introduction to Continuum Mechanics: Morton M. Gurtin.
- Introduction to Continuum Mechanics for Engineers: Ray M. Bowen.
- Continuum mechanics for engineers: G. Thomas Mase and George E. Mase.
- Theory and Problems of Continuum Mechanics: George E. Mase.
- Nonlinear Continuum Mechanics for Finite Element Analysis: J. Bonet and R. D. Wood.
- Continuum mechanics and plasticity: Han Chin Wu.

Course Code: AMN15105	Design and Analysis of Experiments	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Mathematics – I, II

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	To introduce Design of Experiments and its importance in engineering.	2	Understand,
CO2	To study and understand basic statistical methods, analysis of various, blocking factors.	2	Understand
CO3	To study and apply various Factorial experiment techniques in designing engineering problems.	3,4	Apply, Analyze
CO4	To study and apply Regression analysis, Response surface methods and Random effect models in engineering problems.	3,4	Apply, Analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	3	2	2	-	-	-	-	1	1	2	3	3
CO2	3	2	2	3	1	-	-	-	-	2	1	2	3	3
CO3	3	2	3	2	2	-	-	-	-	1	-	2	3	3
CO4	3	3	3	3	1	-	-	-	-	-	2	1	3	3

Module	Syllabus	Hours
1	**Introduction to measurements**: Principles of Measurement, Basic Elements of a Measuring Device, Force and Torque Measurement, Temperature Measurement, Pressure Measurement, Fluid Velocity Measurement, First and second order systems.	4
2	**Experimental design and analysis**: Strategy of Experimentation, applications of Experimental Design, Basic Principles, Guidelines for DoE, Sampling and Sampling Distributions, Randomized Designs, Paired Comparison Designs, Inferences About the mean and Variances of Normal Distributions, Determining Sample Size, The Random Effects Model, The Regression Approach to the Analysis of Variance, Nonparametric Methods in the Analysis of Variance	6
3	**Blocking Factors and Factorial Experiments**: The Randomized Complete Block Design, The Latin Square Design, The Graeco-Latin Square Design, Balanced Incomplete Block Designs, Advantage of Factorials, The Two-Factor Factorial Design, The General Factorial Design, Fitting Response Curves and Surfaces, Blocking in a Factorial Design	6
4	**Two-Level Factorial/ Fractional Factorial Designs:** The General 2^k Design, A Single Replicate of the 2^k Design, Unreplicated 2^k Design, Addition of Center Points to the 2^k Design, blocking a Replicated 2^k Factorial Design, confounding in the 2^k Factorial Design, Confounding the 2^k, Factorial Design in Two Blocks, The One-Half Fraction of the 2^k Design, The One-Quarter Fraction of the 2^k Design, The General 2^{k-p} Fractional Factorial Design.	8
5	**Regression Modeling:** Linear Regression Models, Estimation of the Parameters in Linear Regression Models, Hypothesis Testing in Multiple Regression, Confidence Intervals in Multiple Regression, Prediction of New Response Observations, Regression Model Diagnostics, Testing for Lack of Fit.	6
6	**Response Surface Methodology:** Introduction to Response Surface Methodology, The Method of Steepest Ascent, Analysis of a Second-Order Response Surface, Experimental Designs for Fitting Response Surfaces, Experiments with Computer Models.	6
7	**Random Effects Models:** Random Effects Models, The Two-Factor Factorial with Random Factors, The Two-Factor Mixed Model, Sample Size Determination with Random Effects, Rules for Expected Mean Squares, Approximate *F* Tests. Non-normal Responses and Transformations, Unbalanced Data in a Factorial Design, The Analysis of Covariance, Repeated Measures.	4

References

- Instrumentation, measurement and analysis, Nakra, B. C., and K. K. Chaudhry, Tata McGraw-Hill Education.
- Design and Analysis of Experiments, Douglas C. Montgomery, 8th Edition, Wiley.
- Design and Analysis of Experiments (Springer Texts in Statistics), Angela M. Dean, Daniel Vos

Course Code: AMN16103	Engineering Vibrations	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Mechanics of Solids, Applied Mathematics and Computations

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	Describe fundamentals of mechanical vibrations along with their classification	2, 4	Understand, Analyse
CO2	Differentiate among single, two and multiple degree of freedom (DOF) systems.	2, 3	Understand, Apply
CO3	Analyze, predict and measure the performance of systems undergoing single, two and multiple	3	Apply
CO4	Solve complicated mathematical models using Numerical methods and software applications	6	Evaluate

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	1	-	-	2	-	1	1	3	3	3
CO2	3	3	3	1	1	-	-	-	-	1	1	3	3	3
CO3	3	3	3	1	1	1	1	-	-	1	-	3	3	3
CO4	3	3	3	1	1	1	2	2	1	2	3	3	3	3

Module	Syllabus	Hours
1	**Fundamentals of vibrations**: Objectives, Types of Loadings, Essential Characteristics of Dynamic Problems, Discrete & Continuous systems, Simple harmonic motion, Combination of two simple harmonic motions, Beats, Fourier analysis, Rigid body dynamics vs. Vibration, Formulation of Vibration Problems: Taught String, Axial Vibration of Bar, Torsional Vibration of Shaft, Flexural Vibration of Beam, Membrane	06
2	**Single degree of freedom system**: Analysis of Free and Forced Vibrations, Response to Harmonic, Periodic & Impulsive Loadings, Duhamel's Convolution Integral, Vibration Isolation, Response to General Dynamic Loading	10
3	**Two degree of freedom system**: Free vibrations of spring coupled system, general solution, Torsional vibrations, mass coupled system, bending vibrations in two degree of freedom system, forced vibrations of an undamped, two degree of freedom system, dynamic vibration absorber, forced damped vibrations	05
4	**Multi-Degree of Freedom Systems**: Modeling of Continuous systems as Multi-degree of Freedom systems, Evaluation of Structural Property Matrices and Influence Coefficients, Eigen value problem, solution of the Eigen value problems – solution of the characteristic equation, orthogonality of normal modes, repeated Eigen values, Reduction of dynamic matrices, Analysis of Dynamic Response - Superposition method, Iteration method, transformation method, Rayleigh's Method- Properties of Rayleigh's Quotient, Dunkerley's formula, Holzer's Method-Torsional systems, Jacobi's method, Stodola method, Fundamental Frequency of Beams and Shafts, Direct time integration of linear systems – Explicit & Implicit methods	10
5	**Frequency Domain Vibration Analysis**: Over view, machine-train monitoring parameters, Data base development, vibration data acquisition, trending analysis and failure, node, signature and root cause analysis.	04
6	**Vibration Control in Structures:** Introduction, State space representation of equations of motion, Passive control, Active control and semi active control, Free layer and constrained damping layers, piezo electric sensors and actuators for active control, semi active control of automotive suspension systems.	05

References

- Elements of Vibration Analysis by Meirovitch, TMH, 2001
- Mechanical Vibrations/Schaum Series/ McGraw Hill
- Mechanical Vibrations / SS Rao/ Pearson/ 2009, Ed 4,
- Vibration problems in Engineering / S.P. Timoshenko.
- Mechanical Vibrations /W.T. Thomson / Prentice Hill India
- Mechanical Vibrations – G.K. Grover – S. Chand & CO.
- Acoustics and Noise Control/Smith, Peters & Owen/ Addison-Wesley-Longman, Ed 2

Course Code: AMN16101	Computational Fluid Dynamics	Credits (L-T-P-Cr) : 3-0-2-4

Pre-requisites: Advanced Fluid Mechanics, Thermo-fluids engineering, Applied Mathematics and Computations

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	To understand and mathematically model the problems in fluids engineering	2,3	Understand /Apply
CO2	To discretize the governing equations using various discretization techniques.	2,3	Understand /Apply
CO3	To analyze and evaluate the grid generation for various problems.	4, 5	Analyze / Evaluate
CO4	To analyze and develop new models for external, internal and unsteady flows	6	Create

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	1	1	-	-	-	-	-	-	-	3	3
CO2	3	3	2	1	1	-	-	-	-	-	-	-	3	3
CO3	2	3	2	3	3	-	-	-	-	-	-	2	3	3
CO4	2	3	3	3	3	1	2	-	2	-	-	2	3	3

Module	Syllabus	Hours
1	**Basic ideas of CFD & Governing equations (GE's) of Fluid dynamics:** Introduction to CFD, role of CFD and its applications, future of CFD: Modeling of flow, control volume concept, substantial derivative, physical meaning of the divergence of velocity. Continuity equation, momentum equation, energy equation and its conservation form. Equations for viscous flow (Navier-Stokes equations), equations for inviscid flow (Euler equation). Different forms of GE's, initial and boundary conditions.	10
2	**FVM for Diffusion Problems:** FVM for 1D steady state diffusion, 2D steady state diffusion, 3d steady state diffusion. Solution of discretised equations- TDMA scheme for 2D and 3D flows.	08
3	**FVM for Convection-Diffusion Problems:** FVM for 1D steady state convection-diffusion, Central differencing scheme, Conservativeness, Boundedness, Transportiveness, Upward differencing scheme, Hybrid differencing scheme for 2D and 3D convection-diffusion, Power-law scheme, QUICK scheme.	08
4	**Solution Algorithm for Pressure-velocity Coupling in Steady Flows:** Concept of staggered grid, SIMPLE, SIMPLER, SIMPLEC, PISO algorithm.	06
5	**FVM for Unsteady Flows:** 1D unsteady heat conduction (Explicit, Crank-Nicolson, fully implicit schemes), Implicit mecthods for 2D and 3D problems, Discretization of transient convection-diffusion problems, solution procedure for transient unsteady flow calculations (transient SIMPLE, transient PISO algorithms).	08

In-house solver development on basic CFD problems

References

- "An Introduction to Computational Fluid Dynamics: the Finite Volume Method", H.K. Versteeg and W. Malalasekara, 2nd edition, Pearson Education, England, 2007.
- "Computational Fluid Dynamics for Engineers" B. Andersson & others, 1st edition, Cambridge University Press, U.K., 2012.
- "Computational Fluid Flow and Heat Transfer" (2nd edition), K. Muralidhar and T. Sundararajan, Narosa Publishing, 2004.
- "Numerical Heat Transfer and Fluid Flow", S.V. Patankar, McGraw-Hill, New York, 1980.
- "Principles of Computational Fluid Dynamics", P. Wesseling, Springer-Verlag.

Course Code: AMN16102	Mathematics for Geometrical Modelling	Credits (L-T-P-Cr) : 3-0-2-4

Pre-requisites: Mathematics, Programming skills

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Understand the role of graphics primitives such as points, line and circles.	1, 2	Remember, Understand
CO2	Apply concepts of graphics to create and analyze the mechanism and machine element focusing design engineering problems.	3,4	Apply, Analyze
CO3	Understand the concepts for generation of geometries and shapes for visualization and further applications for analysis.	2,3	Understand
CO4	Apply the concepts for generation of geometries and shapes and analyze the quality of the geometrical model developed.	4	Apply, Analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	-	1	1	1	-	1	-	2	2	2	3	3
CO2	2	2	2	2	3	1	-	1	2	2	1	2	3	3
CO3	3	2	3	3	3	2	2	2	2	2	1	2	3	3
CO4	3	3	2	3	3	2	2	3	2	2	3	2	3	3

Module	Syllabus	Hours
1	**Mathematical representation of graphics primitives:** Points & lines. Algorithm for Lines – DDA algorithm, Bresenham's algorithm, Circle generation algorithms. Character generation, fill area functions, Computer Aided Mechanism and Machine Element Design.	07
2	**Transformations and projections**: Rigid body transformations, Deformations, Generic transformation in two and three-dimensions, Computer Aided Assembly of Rigid Bodies, Projections (Orthographic and Oblique).	06
3	**Representation of curves and its types:** Introduction, Wire frame models, Parametric representation of curves (analytic & synthetic), curve interpolation, manipulation, Differential Geometry of Curves, Ferguson's or Hermite Cubic Segments. Three-Tangent theorem, Bézier Segments, Splines (Polynomial and B Splines), Non-Uniform Rational B-Splines (NURBS)	08
4	**Surface representation:** Surface models, parametric representation, surface manipulation, Blending surface, Deviation of the Surface from the Tangent Plane: Second Fundamental Matrix, Gaussian and Mean Curvature, Surface generation methods (Revolution and Sweep)	07
5	**Representation of solids:** Fundamentals of solid modeling, Topology of Surfaces, Invariants of Surfaces, Boundary representation, constructive solid geometry, Euler-Poincare formula, Euler operators, Constructive solid geometry: CSG primitives, Boolean operators sweep representation, analytic solid modelers, design application.	06
6	**Visual realisation and computer animation:** Model clean-up, hidden line removal, hidden surface removal, shading, colouring and rendering, Computer animation, animation systems, types and technique, design applications, Computer Graphics Standard	06

References

- *Computer graphics*, by Baker.
- *Geometric Modeling* by Mortenson, Wiley Publishers.
- *Computer aided engineering design* by Saxena, & Sahay, Springer Science & Business Media.
- *Mathematical Elements for Computer Graphics* by Rogers and Adams, 2nd Edition, McGraw-Hill Publishers.
- *An Introduction to Splines for Use in Computer Graphics and Geometric Modeling* by Bartels, Beatty, Barsky, Morgan Kaufmann Publication.
- *Curves and Surfaces for Computer Aided Geometric Design* by Farin, Academic Press.

Course Code: AMN17101	Digital Image Processing	Credits (L-T-P-Cr) : 3-0-2-4

Pre-requisites: Linear Algebra and Discrete Mathematics

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	To comprehend the principles and techniques employed in digital image processing.	2	Understand
CO2	To analyze and manipulate digital images, including understanding image properties, representation, and enhancement.	2, 4	Understand, Analyse
CO3	To extract and select relevant features from images, including statistical features, texture features, and shape features.	2, 4	Understand, Analyse
CO4	Understand the application of image processing in medical imaging, including different imaging modalities and the use of image processing techniques for medical image analysis.	2, 3	Understand, Apply
CO5	To apply different segmentation techniques to extract objects of interest from images, employing methods such as thresholding, edge-based segmentation, and region-based segmentation.	3, 5	Apply, evaluate

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	1	-	-	2	-	1	1	3	3	3
CO2	3	3	3	1	1	-	-	-	-	1	1	3	3	3
CO3	3	3	3	1	1	1	1	-	-	1	-	3	3	3
CO4	2	2	3	2	1	-	-	1	1	-	1	2	2	2
CO5	2	2	2	2	1	-	-	-	-	-	1	2	2	2

Module	Syllabus	Hours
1	**Introduction** - Elements of digital image processing systems - Elements of visual perception, brightness, contrast, hue, saturation, mach band effect. Imaging systems - Digital Images - Properties, Types, Image Representation, Image Analysis, Digitization of an analog image. Color image fundamentals - RGB, HSI models.	08
2	**Basic concepts of image processing:** Fundamentals of digital image processing – Gray level histogram, Histogram transformations and look-up tables. Image enhancement in spatial domain - Algebraic operations, Logical (Boolean) operations, Geometric operations, Convolution-based operations. Image enhancement in frequency domain - Fourier Transform, Properties, Standard Representation, Optical Representation. Frequency domain filters - LPF, HPF, BPF, Notch filter, Homomorphic filters. Tomographic reconstruction.	06
3	**Image Segmentation:** Thresholding- global grayscale thresholding, global color thresholding, or local thresholding, Edge-based segmentation, Region-based segmentation, Matching. Morphological Segmentation, Binary morphological operations, element structuring, connectivity, and primary and advanced binary morphology operations.	12
4	**Image feature extraction and selection:** Features- Feature space, Statistical features, Texture features-co-occurrence features and Run length features, shape features. Feature selection – Need-PCA, statistical analysis and selection of features.	04
5	**Application of image processing:** Imaging Modalities - Medical images obtained with ionizing radiation, Medical images obtained with non-ionizing radiation.	10

References

- Image Processing, Analysis and Machine vision by Milan Sonka; Vaclav Hlavac; Roger Boyle, Cengage Learning 4th ed.
- Digital Image Processing by Rafael C. Gonzalez, Richard E. Woods, Pearson Education, 4th ed.
- Digital image processing for medical applications by Geoff Dougherty, Cambridge University Press, 1st ed.
- Fundamentals of Digital Image Processing by Anil K. Jain, Pearson Education, 1st ed.

Electives (I and II)

Course Code: AM-	Optimization - I	Credits (L-T-P-Cr) : 3-0-0-3
Pre-requisites: Mathematics		

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Development of the skill of finding optimum value of desired variable in a real-life engineering problem.	2	Understand,
CO2	Development of knowledge of expressing a real-life problem in terms of mathematics i.e to develop the skill of Mathematical Modeling.	2	Understand
CO3	To develop the skill to apply Linear & Non-linear Programming, Gradient Methods & Artificial Neural Networks etc in real life engineering problems	3,4	Apply, Analyze
CO4	To develop skill of writing Flow Charts of real-life engineering problems and transform those into computer programming	4	Analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	2	1	-	-	-	-	-	-	1	2	3	2
CO2	3	3	2	1	1	-	-	-	-	-	1	2	3	2
CO3	3	3	3	2	1	-	-	-	-	-	1	2	3	2
CO4	3	3	3	3	2	-	-	-	-	-	1	2	3	2

Module	Syllabus	Hours
1	**Introduction to Optimization:** Design variables, Design constraints, Objective function Design space, feasible region, Problem statement, Local and Global optima, Classification of optimization problems, Solution by calculus and numerical methods.	8
2	**Linear and Nonlinear Programming:** Simplex method, Geometric Programming: Application to simple problems. Method of approximation programming, Kelly's Cutting Plane method.	12
3	**Gradient Methods:** Steepest descent and Side step method. Conjugate Gradient method, Rosin's Gradient Projection Method, Zotendik's method of feasible directions, Unconstrained and Constrained Optimization, and penalty function technique search procedures.	12
4	**Introduction to Genetic Algorithm:** Artificial Neural Network, Dynamic programming, Application to Process Equipment, Structural Mechanics, Development of computer programmes	8

References

- Engineering Optimization, Theory and Practice: S. S. Rao
- Optimization of Structural and Mechanical Systems: J. S. Arora
- Elements of Structural Optimization: R. T. Haftka and Z. Gürdal
- Cost Optimization of Structures: Fuzzy Logic, Genetic Algorithm and Parallel Computing: H. Adeli and K. C. Sarma
- An Introduction to Optimization: Edwin K. P. Chong and Stanislaw H. Żak
- Nonlinear Optimization- Theory and Algorithms: L.C.W. Dixon
- Linear Programming Vol.I: G. Hadley
- Nonlinear and Dynamic Programming, Vol.II: G. Hadley

Course Code: AM-XXXXX	Mechanical Behaviour of Materials	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Advanced Mechanics of Solids

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	To Understand various types of deformation and failure of engineering materials subjected to various static and dynamic loadings	2	Understand
CO2	To understand how deformation and fracture occur and how structure affects mechanical behaviour	2	Understand
CO3	To evaluate mechanical behaviour, measurements of mechanical properties and test methods	3,4	Apply and analyze
CO4	To apply fracture mechanics to determine whether a material will fracture before yielding	3,4	Apply and analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	2	1	-	-	-	2	1	1	2	2
CO2	3	3	3	1	1	2	-	-	-	2	1	1	2	2
CO3	2	1	2	1	2	1	-	-	-	1	1	1	2	2
CO4	2	2	2	1	2	3	1	1	1	1	1	1	2	2

Module	Syllabus	Hours
1	**Elasticity:** Linear: Continuum; Isotropic; Anisotropic; Multiaxial; Atomistic Basis, Nonlinear in Crystalline Materials: Pseudo elasticity, Rubber Elasticity: Latex to DNA, Viscoelasticity: Elasticity and Fluidity	**8**
2	**Plasticity:** Limit of Elastic Response: Uniaxial and Multiaxial, Mechanisms in Crystalline Materials: Dislocations, Twins, Mechanisms in Nanocrystalline Materials, Strengthening via Microstructure, Environment, And Physical Size	**6**
3	**Creep:** Time-Dependent Plasticity, Deformation Mechanism Maps of Elasto-plasticity, Creep of Pure Metals, Creep of Ceramics and Polymers, Creep Asymmetry, Super-plasticity in Materials	**6**
4	**Fracture:** Evolution of Fracture Models: Ultimate Failure, Linear Elastic Stress Field in Cracked Bodies – Crack Deformation Modes, - Singular Stress Field and Displacement Fields, Microstructural Mechanisms of Fracture Strengthening,	**8**
5	**Fatigue:** Failure Below Fracture Stress: Insidious Failure, Empirical Fatigue Models, Microstructural Mechanisms of Prolonged Fatigue Lifetime, Characteristics of Fatigue Fracture -Fatigue Crack Propagations Laws, Strain Controlled Fatigue, Fatigue Life Calculations, High Cycle Fatigue Design-Surface Fatigue Failure Models- Dynamic Contact	**8**

References

1. Mechanical Behavior of Materials, 2nd Edition, Thomas H. Courtney
2. Mechanical Behavior of Materials, Engineering methods for Deformation, Fracture and Fatigue, 4th Edition. Norman E. Dowling
3. Mechanical Behavior of Materials, 2nd Edition. Marc Meyers and Krishan Chawla

Course Code: AM-XXXXX	Aerodynamics	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Fluid Mechanics, Compressible Flow

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	To understand fundamentals of Aerodynamics and Flight Principles.	2	Understand
CO2	To analyze various wing configurations of low-speed and high-speed aircrafts.	2,4	Understand and analyze
CO3	To realize the fundamentals of wind tunnels and measuring principles of various flow parameters.	3,4	Apply and analyze
CO4	To understand the latest development and trends in Aerodynamics, newer applications.	3,4	Apply and analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	1	2	2	1	-	-	-	2	1	1	2	2
CO2	1	3	1	3	1	3	-	-	-	2	1	1	2	2
CO3	2	3	2	3	2	3	-	-	-	1	1	1	2	2
CO4	2	2	2	1	2	3	3	-	-	-	1	1	2	2

Module	Syllabus	Hours
1	**Introduction to Aerodynamics:** Hot air balloon and aircrafts, Various types of airplanes, Wings and airfoils, lift and Drag, Centre of pressure and aerodynamic center, Coefficient of pressure, moment coefficient, Application of potential flow in aerodynamic problems.	**8**
2	**Incompressible Flow Theory:** Design of airfoils using conformal transformation, Kutta condition, Karman – Trefftz profiles, Thin aerofoil Theory and its applications. Vortex line, Horse shoe vortex, Biot - Savart law, Prandtl lifting line theory, Panel methods.	**6**
3	**Compressible Flow Theory:** Potential equation for compressible flow, small perturbation theory, Prandtl- Glauert Rule, Linearised supersonic flow, Method of characteristics.	**6**
4	**Airfoils, Wings and Airplane configuration in High-Speed Flows:** Critical Mach number, Drag divergence Mach number, Shock stall, super critical airfoils, Transonic area rule, Swept wings (ASW and FSW), supersonic airfoils, wave drag, delta wings, Design considerations for supersonic airplanes.	**8**
5	**Viscous Flow Measurements:** Types of wind tunnels – Flow visualization processes – Measurement of force and moments in wind tunnels. Measurement of pressure, velocity and wall shear stress, Flow visualizations. **Latest developments and trends in Aerodynamics:** UAV, MAV.	**8**

References

- L.J. Clancey, Aerodynamics, Indian Edition 2006, Sterling Book House, Mumbai.
- J.D. Anderson, "Fundamentals of Aerodynamics", McGraw-Hill Book Co., New York, 1985.
- Rathakrishnan.E., Gas Dynamics, Prentice Hall of India, 1995.
- Shapiro, A.H., Dynamics & Thermodynamics of Compressible Fluid Flow, Ronald Press, 1982.
- E.L. Houghton and N.B. Caruthers, Aerodynamics for Engineering Students, Edward Arnold Publishers Ltd., London, 1988.
- Zucrow, M.J., and Anderson, J.D., Elements of gas dynamics McGraw-Hill Book Co., New York, 1989.
- W.H. Rae and A. Pope, "Low speed Wind Tunnel Testing", John Wiley Publications, 1984.

Course Code: AMN-XXXX	Mechanical System Design	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Solid Mechanics, Engineering Analysis and Design

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Students will be able to apply knowledge of basic science and engineering fundamentals for design of a more complex and diverse engineering system utilizing a systems approach.	1, 2	Remember, Understand
CO2	Students will have ability to communicate within the design group effectively to identify the requirements of a design problem and will be able to formulate and give a tangible solution.	3,4	Apply, Analyze
CO3	Students will be able to evaluate the concepts and designs developed during different phases of the design	5	Evaluate
CO4	Students will be able to test the design by mathematical tools, prototype testing and verify the results.	4	Apply, Analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	-	1	1	1	-	1	-	2	2	2	3	3
CO2	2	2	2	2	3	1	-	1	2	2	1	2	3	3
CO3	3	2	3	3	3	2	2	2	2	2	1	2	3	3
CO4	3	3	2	3	3	2	2	3	2	2	3	2	3	3

Module	Syllabus	Hours
1	Design Process: Types of design work, The role of the designer, creativity, The morphology of the design process; Systems Approach: Fundamentals of Technical System: System, plant, components, equipment, machines, and assemblies; The Application of Systems concepts in Engineering Design, Identification of Engineering functions and engineering characteristics, Conversion of energy, material and signals, Functional relationship, Working interrelationship: physical effects, Product and function decomposition diagram, Engineering Activity Matrix, A case study	**07**
2	Problem Definition and Need Identification, Identifying Customer Needs, System interface, importance and types of requirements, Types of Customer requirements, Functional requirements and company requirements; Gathering Information on Existing Products, Establishing the Engineering Characteristics, Quality Function Deployment, Product Design Specification, Team Behaviour and Tools, Gathering Information, Types of Design Information, Sources of Design Information	**07**
3	Functional analysis and variants: Creative thinking, Functions, classification of functions, functional variants, relocating functions, subdividing functions, combining or eliminating functions, Study of system equation, Physical effects –Physical effects for generating force and other functions, Physical laws and effects relating physical quantities, Solutions for basic functions; Generating concept variants from sub-solutions, case study: Liquid pressure variator; Concept evaluation: absolute and relative, Case study	**07**
4	Decision Making and Concept Selection: Introduction, Decision Making - Behavioral aspects of decision making, Decision theory, Decision tree; Evaluation processes, Using models in evaluation, Pugh Concept selection process, Weighted Decision Matrix, Analytic Hierarchy Process (AHP)	**04**
5	Configuration – Product architecture and Part design, Embodiment/Parametric – Steps in parametric design, Belt and Pulley example and Detail design, Manufacturing considerations in design, guidelines in designing for assembly	**05**
6	Mathematical Modelling Concepts: Models – Iconic, Analog, symbolic and a proof-of-concept, prototype; Choosing appropriate model, Aids to mathematical modelling – Dimensional analysis, scale model, A Process for Mathematical Model Building, Geometric modelling, Finite Element Method, Case Study	**05**

References

- G.E.Dieter, “Engineering Design: A Materials and Processing Approach” McGraw Hill.
- Hundal, M. S., “Systematic Mechanical Designing: A Cost and Management Perspective’’, New York, ASME Press,1997.
- J.R.Dixon, “Design Engineering and design for manufacture” Field Stone Pub.
- David G.Ullman, “The Mechanical Design Process”, McGraw Hill
- R.J.Eggert, “Engineering Design”, Pearson/Prentice Hall.
- Martin S Ray, “Elements of Engineering Design”, Prentice Hall
- Principles of Design: Nam P Suh, McGraw Hill 1999
- Total Design**:** Stuart Pugh, Pearson Education

Course Code: AM-XXXXX	Structural Mechanics	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Engineering Mechanics, Mechanics of Solids

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	Students will be able to understand different type of plane structures and possible loadings on such structures	2	Understand
CO2	Students will be able to analyse plane structures and evaluate deflections, reactions and internal forces for trusses, beams and frames	4, 5	Analyze, Evaluate
CO3	Students will be able to extend the study of linear elastic analysis to include nonlinear aspects of structure behaviour	3	Apply
CO4	Students will be able to understand the basic construction of bridges	3,4	Understand

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	2	1	-	-	-	2	1	1	3	2
CO2	3	3	3	1	1	2	-	-	-	2	1	1	3	3
CO3	2	1	2	1	2	1	-	-	-	1	1	1	2	2
CO4	2	2	2	1	2	3	1	1	1	1	1	1	3	2

Module	Syllabus	Hours
1	**Analysis of Plane Structures:** Introduction and Classification of Structures, Review of AFD, SFD and BMD for Beams, Degrees of Freedoms, Static and Kinematic Indeterminacy of Structures, Analysis of Compound and Complex Trusses, Analysis of Plane Frames, Displacements of Plane Structures, Maxwell's Reciprocal & Betti's Theorem, Unit Load method, Deflection of trusses and plane frames	**10**
2	**Rolling loads and Influence Line Diagrams:** Introduction, Influence Line Diagrams for Beams & Trusses, Absolute Maximum Bending Moments, Muller- Breslau principle and its applications	**6**
3	**Matrix Method of Analysis:** Introduction, Flexibility Method- Application to Beams, Trusses, Frames and Grid Structures; Stiffness Method- Application to Beams, Trusses, Frames and Grid Structures (including plane and space structures)	**10**
4	**Plastic Analysis of Structures:** Introduction, Plastic Analysis of Beams, Frames & Gable Frames.	**6**
5	**Arches, Cables and Suspension Bridges**: Introduction, Linear Arch, Eddy's Theorem, Three-Hinged & Two-Hinged Arches, Spandrel Braced Arch, Influence Lines for Arches, Analysis of Cables, Suspension bridges with three and two hinged stiffening girders	**8**

References

- Structural Analysis, Hibbeler, Pearson Publications.
- Structural Analysis, Aslam Kassimali. Cengage Learning Publications.
- Structural Analysis in Theory and Practice, Alan Williams, Elsevier Publications
- Elementary Structural Analysis, C. H. Norris, J. B. Wilbur and S. Utku., Tata Mcgraw Hill Publications
- Structural Analysis, L.S. Negi and R. S. Jangid, Tata Mcgraw Hill Publications
- Intermediate Structural Analysis, C. K. Wang, Tata Mcgraw Hill Publications
- Matrix Analysis of Framed Structures, W. Weaver (Jr.) and J. M. Gere, CBS Publications.

Electives (III and IV)

Course Code: AM-	Optimization-II	Credits (L-T-P-Cr) : 3-0-0-4
Pre-requisites: Optimization-I		

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	To understand the basics of Optimization.	2	Understand,
CO2	To understand the basics of Genetic Algorithm.	2	Understand
CO3	To be able to apply the basics of Genetic Algorithm and optimization for real life practical engineering applications.	3,4	Apply, Analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	3	2	2	-	-	-	-	1	1	2	3	3
CO2	3	3	3	3	1	-	-	-	-	2	1	2	3	3
CO3	3	2	3	2	3	-	-	-	-	1	-	2	3	3

Module	Syllabus	Hours
1	Basics of Optimization, Optimization Problems, Point to Point Algorithms, Simulated Annealing; Population Based Algorithms, Brief Overview of Evolutionary Computation,	**12**
2	Genetic Algorithms (Theory and Advanced Operators), Genetic Representation, search operators, selection schemes and selection pressure; Operators on Real-valued Representations, Niche and fitness sharing, Particle Swarm Optimization,	**12**
3	Memetic Algorithms; Evolution Strategies, Genetic Programming, Evolutionary Programming, Differential Evolution; Constraint Handling in optimization problems,	**08**
4	Real Life application of optimization Algorithms, Introduction of Multi-objective Evolutionary Algorithms	**08**

References

- Goldberg, David E. "Genetic algorithms in search, optimization, and machine learning. Addison." *Reading* (1989).
- Industrial applications of Genetic Algorithms by Charles L Karr and L.Michael Freeman, CRC Press
- Lawrence, Davis. "Handbook of genetic algorithms." *Van Nostrand Reinhold* (1991).

Course Code: AM-XXXXX	Soft Robotics	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Biology for Engineers, Fluid Mechanics, Mechanics of Solids, Dynamics of Mechanical Systems

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	Understanding the fundamentals of soft Robotics, including materials, sensing and actuation mechanisms, design principles, and applications.	2,4	Understand, Analyse
CO2	Understand the connection between biology and robotics and how biology inspires robotics	2,3	Understand, Apply
CO3	Explain the impact of morphological features of soft robot bodies and environment on performance.	3,4	Apply, Analyse
CO4	Apply soft technologies, materials, actuation and sensing system to real world applications.	3,4	Analyse, Apply

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	1	-	-	2	-	1	1	3	3	3
CO2	3	3	3	1	1	-	-	-	-	1	1	3	3	3
CO3	2	2	2	1	1	-	-	1	-	-	-	2	2	2
CO4	2	3	2	1	1	1	1	-	-	1	1	2	2	2

Module	Syllabus	Hours
1	**Introduction to soft robotics:** definitions, difference soft robots vs. rigid Robots, Bioinspired design.	**6**
2	**Polymeric materials for soft robotics:** Elastomers, Thermoplastics and textiles, Advanced materials. **Soft actuation -** design, modelling, manufacturing, and characterization. **Soft robotic actuation modalities -** Fluidic actuation, Electrostatic/Electrochemical Actuation (Dielectric elastomer actuators, hydraulically amplified electrostatic actuators, Ionic polymer–metal composite actuators), Thermal Actuation (Shape memory alloys), Magnetic Actuation, Biohybrid Actuation, Additional actuation (Mammalian and non-Mammalian origin).	**10**
3	**Sensors:** Resistive and piezoresistive sensors, Conductive liquid sensors, Capacitive sensors, Optical fiber sensors, Optical fiber sensors, soft logic, soft electronics and soft sensing, Modeling and simulation of soft robots.	**8**
4	**Variable Stiffness mechanisms:** Introduction to variable stiffness structures, Jamming mechanisms.	**6**
5	**Design and control of soft robots:** Typical soft robot architectures, On-board control strategies (Model-Based Control, Data-Based Control). Applications of soft robotics.	**6**

References

- Biologically inspired robotics by Yunhui Liu and Dong Sun., CRC press, 2011
- Soft Robotics: Transferring Theory to Application by Alexander Verl, Alin Albu-Schäffer, Oliver Brock, and Annika Raatz, Springer, 2015.
- Biorobotics by Barbara Webb, Thomas R. Consi, AAAI Press, 2001
- An Overview of Soft Robotics by Oncay Yasa *et al*. Annual Review of Control, Robotics, and Autonomous Systems
- Physiology for Engineers: Applying Engineering Methods to Physiological Systems by Michael Chappell and Stephen Payne, Biosystems & Biorobotics Volume 15, Springer, 2015.
- Soft Robotics in Rehabilitation by Amir Jafari and Nafiseh Ebrahimi, Academic Press, 2021.

Course Code: AM-XXXXX	Characterization of Materials	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Materials Science and Engineering

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	Students will have knowledge and understanding of the basic concepts of the materials characterization techniques such as X-ray diffraction, Microscopy	2	Understand
CO2	Students will be able to analyze samples with the help of collected data by using different materials characterization techniques	4	Analyze
CO3	Students will have the capability to decide most appropriate technique required for the investigation of the structure and properties of different classes of materials	3	Apply

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	1	-	-	2	-	1	1	3	3	3
CO2	3	3	3	1	1	-	-	-	-	1	1	3	3	3
CO3	2	2	2	1	1	-	-	1	-	-	-	2	2	2

Module	Syllabus	Hours
1	**Crystallography:** Overviews in bonding, Bravais lattices, Miller indices, imperfections in crystals, crystal structures of common metal, ceramics, polymers. symmetries in crystals, point groups, space groups, reciprocal lattice, morphology	5
2	**X-ray Diffraction Techniques:** Production of X-rays, its properties and hazards, photon scattering, X-ray diffraction and Bragg's law, intensities calculations, Laue techniques, Debye-Scherrer techniques. modern diffractometers, diffractometer measurements, determination of crystal structure of powder sample, small angle scattering, line broadening, particle size, crystallite size, residual stress measurement, plane indexing, precise parameter measurement, phase identification, phase quantification, phase diagram determination, stereographic projection, pole figure, preferred orientation (texture analysis) and chemical analysis, profile fitting and Rietveld analysis.	9
3	**Optical Microscopy:** Principles and operations of microscopy, resolution, magnification, numerical aperture, depth of field, viewing area, contrast, geometry of optical microscopes, application of microscopy in metallurgical studies (qualitative and quantitative), morphology and symmetry, grain boundaries and dislocations, phase contrast microscopy, polarised light microscopy, hot-stage microscopy, sample preparation.	9
4	**Electron Microscopy:** Electron sources, electron diffraction, principles and operation of scanning electron microscope. geometry of electron microscopes, specimen handling and preparation, secondary electron image, backscattered electron image, image processing, analysis of electron micro-graphs and fractography studies, transmission electron microscopy (TEM).	8
5	**Scanning Probe Microscopy:** Principles and operation of scanning probe microscopes, scanning tunnelling microscope, atomic force microscope, magnetic force microscopy, topography studies, nanoindentation and its probing.	5
6	**Thermal Analysis:** Thermo gravimetric analysis, differential thermal analysis, differential scanning calorimetry, thermo-mechanical analysis and their applications.	4

References

- Crystals and Crystal structures, R.J.D. Tilley, John Wiley and Sons, 2006
- Elements of X-ray Diffraction, Cullity B. D., Addison-Wesley Publishing Co.
- Electron Microscopy and Analysis, P.J. Goodhew, F.J. Humphreys, Taylor & francis, Second edition.
- Solid state chemistry and its Applications, Antony R. West, Wiley Student Edition.
- Fundamentals of Molecular spectroscopy, Colin N. Banwell and Elaine M. McCash, Tata McGraw-Hill Publishing
- Materials Characterization: Introduction to Microscopic and Spectroscopic, Yang Leng, John Wiley&Sons.

Course Code: AM-XXXXX	Product Design and Development	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Engineering Analysis and Design

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	Students will be able to visualize different products lying in the same category –but that has been designed covering different set of needs	2,4	Understand, Analyze
CO2	Students will be able to feel themselves more knowledgeable- at the end of the course.	2	Understand
CO3	Students will be able to identify needs and be able to suggest different alternative solutions considering cost constraints.	3	Apply
CO4	Students will be able to have a watchful eye on happenings in their surrounding for creative analyses. Possibility of taking up entrepreneurship activity, possibility of coming up with new ideas leading to IPR.	3, 4	Apply and analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	2	2	2	2	-	-	-	2	2	2
CO2	3	3	3	2	2	2	2	2	-	-	-	2	2	2
CO3	3	3	3	2	2	2	2	2	-	-	-	2	2	2
CO4	3	3	3	2	2	2	2	2	-	-	-	2	2	2

Module	Syllabus	Hours
1	**Introduction**-Introduction to product design, Significance of product design, product design and development process, sequential Engineering design method, the challenges of product development, Development Process and Organizations-Generic Development Process, Concept Development, Adapting the generic PD process flows, AMF development Process, Product Development Organizations, The AMF Organization.	8
2	**Product Planning and Identifying Customer Needs**-Product Planning process, interpret raw data in terms of customers need, organize needs in hierarchy and establish the relative importance of needs, review of the process. Product Specifications Establish target specifications, setting final specifications.	8
3	**Concept Generation-**Activities of concept generation, clarifying problem, search both internally and externally, explore the output, Concept Selection-Overview, concept screening and concept scoring, methods of selection. Concept Testing-Elements of testing: qualitative and quantitative methods including survey, measurement of customers' response. Product Architecture-Modular and Integral architecture, implications, establishing the architecture, Delayed differentiation, Platform Planning. Industrial Design- Assessing need for industrial design, Impact of industrial Design, industrial design process, management of industrial design process, assessing quality of industrial design.	10
4	**Embodiment Design:** Design for Manufacturing, prototyping. Robust Design. Intellectual Property and Environmental Guidelines-Intellectual Property: Elements and outline, patenting procedures, claim procedure, Environmental regulations from government, ISO system.	8

References

- Ulrich K. T, and Eppinger S. D, Product Design and Development
- Otto K, and Wood K, Product Design

Course Code: AM-XXXXX	Biofluid Dynamics	Credits (L-T-P-Cr) : 3-0-0-3
Pre-requisites: Biology for Engineers, Advanced Fluid Mechanics		

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	To understand basic concepts of fluid mechanics in context of physiological flow in human body		Understand, Analyze
CO2	To understand the rheological of body fluids such as blood		Understand
CO3	To analyse physiological flows in human circulation and respiratory systems.		Understand
CO4	To design and analyse biofluid mechanics problems related to clinical applications		Apply and analyze

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	1	1	-	-	-	2	1	1	3	2
CO2	3	3	3	2	1	2	-	-	-	2	1	1	2	3
CO3	3	2	2	2	1	1	-	-	-	2	1	1	2	2
CO4	3	2	2	2	2	3	1	1	1	2	2	2	3	3

Module	Syllabus	Hours
1	**Introductory Fluid Mechanics:** Fluid Properties, Basic Laws, Governing Equations; Laminar Flow, Couette Flow, and Hagen-Poiseuille Equation.	8
2	**Blood Rheology:** Blood Composition, Blood Rheology, Relationship between Blood Composition and Rheology, Constitutive Equation for Blood, Large Artery Hemodynamic, Steady Blood Flow at Low Flow Rates, Unsteady Flow in Large Vessels	6
3	**Circulatory System:** Anatomy of the Vasculature, Gross anatomy of Heart, Cardiac pumping process, Cardiac Cycle, Cardiac Pumping Power and Ventricular Function, Arterial Pulse Propagation, Systolic and Diastolic pressure, Windkessel Model, Arterial Wall Structure and Elasticity, Pressure–Flow Relationships: Purely Oscillatory Flow, Osmotic Pressure, The Capillaries, The Veins, Cardiac Valve Dysfunctions and Heart Failure**.**	6
4	**The Interstitium:** Interstitial fluid flow, Darcy's law, Clearance of Edema, Detailed parameter derivation **Ocular Biomechanics:** Ocular anatomy, Biomechanics of Glaucoma, Tonometry, Drainage of Aqueous Humor in Normal and Glaucomatous Eyes, Drainage of Aqueous Humor in Normal and Glaucomatous Eyes, Ocular Blood Flow, Optic Nerve Head Biomechanics,	8
5	**Respiratory System:** Gross Anatomy and Physiology, Biofluid Dynamics of Breathing, Lung Elasticity and Surface Tension Effects, Flow Behaviour in Upper and Lower Human Respiratory System during Different Breathing Conditions, Studies of Wall Shear Stress and Its Implications, Mass Transfer in Lungs, Particle Transport in the Lung,	8

References

- Ethier, C. R., & Simmons, C. A. (2007). Introductory biomechanics: from cells to organisms. Cambridge University Press.
- "Biomechanics: Motion", Flow, Stress, and Growth", Y.C. Fung, Springer-Verlag, 1990
- J.N. Mazumdar, "Bio-fluid Mechanics", World Scientific, 1992.
- R.M. Berne, M.N. "Cardiovascular Physiology", Levy, 8th Edition, Mosby, 2001.
- C. Klienstreuer, "Bio-fluid Dynamics", Taylor & Francis.

B.Tech. (Honors)

(16-20 credits, during 5th to 7th semester)

Course Code: AM-XXXXX	Advanced Biomechanics	Credits (L-T-P-Cr) : 4-0-0-4
Pre-requisites: Biology for Engineers, Biomechanics		
	Syllabus	
Kinematics: Body Segment Parameters: Method of Measuring and Estimating Body Segment Parameters, Two Dimensional and Three-Dimensional Computational Methods. **Two-Dimensional Inverse Dynamics**: Planar Motion Analysis, Numerical Formulations, Human Joint Kinetics. Three-Dimensional Kinetics: Data Required for Three-Dimensional Analysis, Anthropometry and Three-Dimensional Kinetics Calculations **Computer Simulation of Human Movement:** Mathematical Formulations, Free Body Diagrams, Lagrange's Equation of Motion, Numerical Solution Techniques, Control Theory, Advantages and Limitation of Computer Models. **Mechanics at the Nanoscale:** Intermolecular Forces and Their Origins; Single Molecules; Thermodynamics and Statistical Mechanics, Motion at the Molecular and Macromolecular Level, Experimental Methods at the Single Molecule Level - Optical and Magnetic Traps, Force Spectroscopy, Light Scattering. **Cellular Mechanics:** Static and Dynamic Cell Processes; Cell Adhesion, Migration and Aggregation; Mechanics of Biomembranes; The Cytoskeleton and Cortex **Tissue Mechanics:** Elastic (Time Independent); Viscoelastic and Poroelastic (Time-Dependent) Behavior of Tissues; Continuum and Microstructural Models; Constitutive Laws; Electromechanical and Physicochemical Properties of Tissues; Physical Regulation of Cellular Metabolism; Experimental Methods - Macroscopic Rheology.		
	References	
• Fung, Y. C. Biomechanics: Mechanical Properties of Living Tissues. New York, NY: Springer-Verlag, 1993. • Nossal, R., and L. Lecar. Molecular and Cell Biophysics. Cambridge, MA: Perseus Books, 1991. • Lodish, H., et. al. Molecular Cell Biology. New York, NY: Scientific American Books/W.H. Freeman, 1995. • Dill, K. A., and S. Bromberg. Molecular Driving Forces. New York, NY: Routledge, 2002. ISBN: 9780815320517. • Nihat Ozkaya and Margareta Nordin Fundamentals of Biomechanics: 3rd Edition. VNR, New York. • David A. Winter Biomechanics and motor control of Human Movements: 3rd Edition, John Wiley & Sons, Inc. • D. Gordon, E. Robertson, Graham E. Caldwell, Joseph Hamill Research Methods in Biomechanics: Human Kinetics		

Course Code: AM-XXXXX	Biomimetics	Credits (L-T-P-Cr) : 4-0-0-4
Pre-requisites: NIL		
Module	**Syllabus**	**Hours**
Intro to bio inspired design, Case Studies. Biological vs Human Solutions, Evolution and rate of innovation, Nature as mentor, source of inspiration, Self-healing, Self-assembly, Hierarchal structures, Structure-function relationship in biological systems, Biomineralization, Bioprocesses, Systems Organization: Bees as a model, Locomotion: Control, balance, gait Bio-inspired robotics, Design Challenges, Design Process, Requirements, abstraction, process, Problem decomposition, Representation and Analogical thinking, Inventions inspired by nature for biomedical applications		
	References	
• Benyus, J. M. (1997). Biomimicry: Innovation inspired by nature (pp. 9-10). New York: Morrow. • Peter Forbes, The Gecko's Foot: Bio-inspiration: Engineering New Materials from Nature, W. W. Norton & Company , May 17, 2006 • National Research Council, Inspired by Biology, The National Academies Press , 2008		

Course Code: AM-XXXXX	Poromechanics	Credits (L-T-P-Cr) : 4-0-0-4
Pre-requisites: Heat Transfer, Advanced Fluid Mechanics, Finite Element Methods		

Syllabus

Introduction: Concept of volume fraction; particle scale; continuum scale, Flow Through Porous Media: General conservation laws; constitutive assumptions; Darcy's law; Richards's equation

FE Formulation of Transient Fluid Conduction Problem: Strong and weak forms; Galerkin approximation; matrix problem; solution of elliptic and parabolic systems; time-integration algorithms-stability and accuracy.

FE Formulation of Solid Deformation Problems: General conservation laws; constitutive assumptions; Hookean and non-Hookean materials; strong and weak forms; Galerkin approximation; matrix problem.

Coupled Solid Deformation-Fluid Flow Problems: Mixed variational principles; time integration for 'mixed' parabolic systems, stability and accuracy; incompressibility constraint; the Lagrange multipliers and penalty methods, Advanced Topics on Mutliscale Simulations for Porous Media

References

- R. de Boer, Theory of Porous Media, Highlights in the Historical Development and Current State, Springer Verlag, 2000
- L.E. Malvern, Introduction to the Mechanics of a Continuous Medium, Prentice Hall, Englewood Cliffs, NJ, 1969
- T. J. R. Hughes, The Finite Element Method, Prentice-Hall, Englewood Cliffs, NJ, 1987
- J. Bear, Dynamics of Fluids in Porous Media, Dover Publications, NY, 1972

Course Code: AM	Mechanics of Composite Materials	Credits (L-T-P-Cr) : 4-0-0-4
Pre-requisites: Continuum Mechanics / Solid Mechanics, Basic Engineering Mathematics, Linear Algebra, Differential Equations		

Syllabus

Introduction: Classification and characteristics of composites, Conventional vs. Composite materials, Advantages and limitations, Salient applications in various fields, Fabrication technologies, Properties of matrix and reinforcement materials.

Micromechanics: Fiber volume fraction, micro-mechanical relations, determination of strength and stiffness, Environmental effects-Hygro-thermal behavior.

Macromechanics: Basic stress-strain relationships for anisotropic materials, engineering constants for orthotropic materials, stress-strain relations for a lamina of arbitrary orientation, effective moduli, invariant properties of anorthotropic lamina, special cases of laminate stiffness, laminate strength analysis, concept of inter-laminar stresses and delamination.

Failure theories and Damage mechanics: Failure mechanisms, maximum stress theory, maximum strain theory, Tsai-Hill theory, Tensor polynomial failure criterion, first ply failure theory, Introduction to damage theory based on continuum damage mechanics.

References

- Mechanics of fibrous composites: Carl T. Herakovic
- Principles of Composite Material Mechanics: R. F. Gibson
- Mechanics of Composite Materials: R. M. Jones
- Introduction to Composite Material: Stephen W.Tsai and H. Thomas Hahn
- Composite Materials and their use in Structures: J. R. Vinson and T.W. Chou

Course Code: AM	Multiscale Modelling	Credits (L-T-P-Cr) : 4-0-0-4

Pre-requisites: Continuum Mechanics / Solid Mechanics, Differential Equations

Syllabus

Introduction: Examples and motivation for exploring multiscale behaviour of materials, Relevant material properties at different scales.
Review of Preliminaries: Prerequisite mathematics, Fundamentals of Thermodynamics and statistical mechanics.
Molecular Dynamics and Related Issues: Particle-based methods, EAM/MEAM potentials: bridging from QM, Atomistic Plasticity, Damage & Fatigue, Molecular Dynamic Simulation Methods.
Meso-scale methods: Overview and need, Quasi-continuum methods, Density Functional method.
Homogenization and Bridging: Multi-scale homogenization and stochastic homogenization, Inter-scale exchange and Scale bridging.
Computational Application: Variational multiscale methods, Numerical resolution and asymptotic behaviour of stochastic PDEs, Enriched continuum models and design.

References

- An Introduction to Multiscale Modelling with Applications, Pietro Asinari and Eliodoro Chiavazzo, Societa Editrice Esculapio
- The Art of Molecular Dynamics Simulation, D. C. Rapaport, Cambridge University Press
- Molecular Dynamics Simulation: Elementary Methods, J. M. Haile, Wiley
- Material Inhomogeneities and their Evolution: A Geometric Approach, Marcelo Epstein · Marek Elzanowski, Springer
- Principles of Multiscale Modeling, E Weinan, Cambridge University Press

Course Code: AM-	Structural Reliability	Credits (L-T-P-Cr) : 4-0-0-4

Pre-requisites: Mathematics

Syllabus

Introduction: Course Overview, Basic Statistics, Theory of Probability, Probability Distributions (Continuous & Discrete), Random Variables
Analytical Methods Reliability Analysis: Failure Surface & Definition of Reliability in Normal Space (Cornell's Reliability Index), First Order Reliability Method (FORM), Hasofer-Lind's Definition of Reliability, Rackwitz-Fiessler Algorithm, Asymptotic Integral, Second Order Reliability Method (SORM)
Simulation Methods: Monte-Carlo Methods Latin Hypercube Sampling, Variance Reduction Technique, Importance Sampling and Adaptive Sampling, Subset Simulation
Stochastic Analysis: Implicit Performance Function, Polynomial Response Surface Method (RSM), Stochastic Response Surface Method (SRSM), Stochastic Models of Loads, Code Calibration, Partial Safety Factors, LRFD Format, System Reliability, Time Varying Reliability Analysis
Additional Topics: Reliability Based Optimization, Introduction to Stochastic FEM, Case Studies, Term Project.

References

- Probability, Statistics and Reliability for Engineers and Scientists: Ayyub B. M, McCuen R. H.
- Probability, Random Variables and Stochastic Processes: Papoulis A.
- Structural Reliability Analysis and Design: Ranganathan R.
- Structural Reliability: Analysis and Prediction: Melchers R E.
- Methods of Structural Safety: Madsen H O, Krenk S. and Lind N. C.
- Reliability Based Structural Design: Choi S. K, Grandhi R. V. and Canfield R A.
- Reliability and Optimization of Structural Systems: Rackwitz R., Augusti G. and Borri A.
- Structural Reliability Using Finite Element Methods: Waarts P. H.,
- Reliability Assessment Using Stochastic Finite Element Analysis: Haldar A. and Mahadevan S.
- Computational Analysis of Randomness in Structural Mechanics: Bucher C.

Course Code: AM-	Structural Stability and Dynamics	Credits (L-T-P-Cr) : 4-0-0-4

Pre-requisites: Advanced Solid Mechanics, Engineering Vibrations

Syllabus

Introduction: Concepts of Stability, Equilibrium path, Stability criteria, Method of Neutral Equilibrium; Recapitulation of Critical Load for Euler Column, Effective-length concept and design curve, Effects of Imperfections / Initial curvature, Eccentricity of loading etc.; Inelastic buckling of columns, Double and Tangent Modulus theory, Shanley's theory, Beam-Columns, buckling by torsion and torsion-flexure

Stability of Plates and Shells: Differential Equations of plate Buckling linear theory, stability of rectangular plates under axial compression and shear, Effect of imperfections, post-buckling behavior of plates; Stability of cylindrical **Shells** under uniform axial pressure and torsion, Effect of imperfections.

Introduction to dynamics of continuous systems: Objectives, Types of Loadings, Essential Characteristics of Dynamic Problems of continuous systems, Formulation of the Equation of Motion

Continuous Systems: Eigen Value Problems and Orthogonality of Natural Modes, Rayleigh's Method, Rayleigh-Ritz Method, Free vibration of strings, bars & shafts, Beams- Coupled natural modes, Effects of Rotary inertia and Shear, Natural Vibrations of Plates, Discretization of continuous systems: Dynamics matrix for flexural, axial & Torsional effects, Numerical Evaluation: Finite Difference, Newmark's, Wilson's, Houbolt's Method, Introduction to Nonlinear Vibration.

Random Vibrations: Stationary & Ergodic Random processes, correlation and autocorrelation functions, power spectral density function, Response of Discrete and Continuous systems to Random excitations.

Introduction to Nonlinear Analysis

References

- Theory of elastic Stability: S. P. Timoshenko and J. M. Gere
- Principles of Structural Stability Theory: A. Chazes
- Background to Buckling: H.G.Allen and P.S.Bulson
- Structural Stability of Columns and Plates: N.G.R.Iyengar
- Dynamics of Structures: W C Hurty and M F Rubinstein
- Structural Dynamics: M. Mukhopadhyay
- Dynamics of Structures: Clough and Penzien.
- Structural Dynamics: Theory and Computation: Mario Paz.
- Dynamics of Structures: J L Humar

Course Code: AM-	Advanced Heat Transfer	Credits (L-T-P-Cr) : 4-0-0-4

Pre-requisites: Heat Transfer

Syllabus

Introduction - Review of fundamentals of heat transfer. Conduction: General heat conduction equation, Analytical solutions of two-dimensional steady state heat conduction; Transient conduction. Convection: Governing equations, boundary layer equations, Forced convection over external surfaces and internal ducts; Similarity solutions. Free and Mixed convection flows, Conjugate heat transfer analysis. Radiative Heat Transfer: Thermal radiation, Emissive Power, Solid Angles, Radiative Intensity, Heat Flux, Pressure and Characteristics, Radiative transport equation.

References

- D.P. Incropera, P.P. and Dewitt, Fundamentals of Heat and Mass Transfer, Wiley Eastern
- Adrian Bejan, Convective Heat Transfer, Wiley India.
- Cengel Y A, Heat Transfer – A Practical Approach, McGraw Hill
- Kays, Crawford and Weigand, Convective Heat and Mass Transfer, McGraw Hill.
- Siegel and Howell, Thermal Radiation, McGraw Hill.
- Kraus A.D., Aziz, A., and Welty, J., Extended Surface Heat Transfer, McGraw Hill
- Adrian Bejan, Allan D. Krams, Heat Transfer Handbook, John Wiley & Sons. 8. J. P. Holman, Heat Transfer, McGraw Hill

Course Code:	Boundary Layer Theory	Credits (L-T-P-Cr) : 4-0-0-4

Pre-requisites: Advanced Fluid Mechanics, Heat Transfer.

Syllabus

Incompressible Laminar Boundary Layers: Exact solutions of the NavierStokes equation exhibiting boundary layer at low viscosity. The boundarylayer equations in the spirit of Prandtl. Scaling, non-dimensionalisation and Reynolds number. Limitations of potential flow past a cylinder. Prandtl's boundary-layer equations in two dimensions deduced by order-of-magnitude arguments. Blasius solution: displacement thickness, skin friction, drag.
Transition and Incompressible Turbulent Boundary Layers: Concept of stability; basis of boundary layer stability analysis; physics of transition to turbulence. Reynolds stresses, mean velocity and shear stress in a turbulent boundary layer; the log law and power law profiles. Turbulent boundary layers in zero and non-zero pressure gradients. Separation in adverse pressure gradients. Concept of and occurrence in steady flows, and at rear stagnation point of impulsively started cylinder.
Boundary Layer Separation & Flow Control: Causes of boundary layer separation and its consequences, active and passive flow control, various different flow control techniques and their applications.
Introduction to Perturbation Theory: Regular and singular perturbations. Examples from algebraic equations and ordinary differential equations. The classical boundary-layer equations of Prandtl as the leading term in a matched asymptotic expansion. Exact solutions of the classical boundary-layer equations like Flow past a wedge: Falkner Skan. Far wake of a flat plate. Two-dimensional jet. Lock's mixing layer. Prandtl transformation. PrandtlGlauert law for subsonic flow; Ackeret's law and applications. Axisymmetric
flows: Mangler's transformation. Split disc Ekman layer problems: Stewartson layers. Glauert wall jet.
Thermal Boundary Layer: Introduction to thermal boundary layer, heat transfer in boundary layer, convective heat transfer, importance of non-dimensional numbers, Prandtl number, Nusselt number, Lewis number etc.

References

- "Boundary Layer Theory", Schlichting, H., McGraw Hill Inc.
- "The Laminar Boundary-Layer Equations", Curle, N., Oxford University Press.
- "Laminar Boundary Layers", Rosenhead, L. (Edited), Oxford University Press.
- "An Introduction to Fluid Mechanics", Batchelor, G. K., Oxford University Press.
- "Separation of Flow", C.T. Chung, McGraw Hill Inc.

Course Code:	Turbulent Flows	Credits (L-T-P-Cr) : 4-0-0-4

Pre-requisites: Engineering Fluid Mechanics, Thermodynamics, Engineering mathematics, Statistical methods.

Syllabus

Introduction: Flow instability and transition to turbulence, Nature of Turbulence, Indicial notation for tensors, Fourier transforms and Parseval's theorem. **Governing Equations of Turbulence, Eulerian, Lagrangian and Fourier descriptions of turbulence Statistical description of turbulence:** Reynolds Averaged Navier-Stokes equations, Reynolds stress evolution equations. **Kolmogorov's Hypothesis:** Diffusivity of turbulence and turbulence length scale. **Filtered Description of Turbulence:** Bridging methods and large eddy simulation (LES).
Turbulent Free Shear Flows: Free Shear Flows- jet flows including heat transfer- 2D flows, wall jet and plane jets, its structure; turbulent jets, turbulent mixing layer and buoyancy effects- its structure; turbulent wake flows, wake of self-propelled bodies; wall-bounded shear flows- its structure; boundary layer flows; thermal plume.
Dynamics of Turbulence: Linear Instability Theory, Nonlinear Stability Analysis, Dynamical Systems, Introduction to Chaos. Vorticity dynamics Reynolds stress and vorticity, vortex stretching, mean vorticity equation, kinetics energy and mean flow, kinetic energy of fluctuations, energy cascade, dissipation, material element deformation, mixing Navier-Stoke's equation for turbulent flow, turbulent energy dissipation equation.
Turbulence modeling: General comments on turbulence models; Method of solving turbulent equations- Direct numerical simulation (DNS), Large-eddy simulation (LES), Reynolds averaged Navier-Stokes equation (RANS), k-€ models. Turbulence models: Eddy viscosity models -zero equation models (constant eddy viscosity and mixing length models), one equation models, two equation models; Reynolds stress transport models (RSM). Wall treatments.

References

- "Turbulent Flows", S.B. Pope, Cambridge University Press, 2000.
- "Turbulence Modeling for CFD" David C. Wilcox, DCW Industries, 3rd Edition, 2006.
- "Viscous Fluid Flow", F.M. White, Tata McGraw Hill, 2011.
- "A First Course in Turbulence", H. Tennekes and J.L. Lumley, The MIT Press, 1972.
- "Turbulence", O. Hinze, McGraw Hill Inc.
- "Turbulent Flow: Analysis, measurement and Prediction", Bernard, P.S., A.D. Wallace, J.M., John Wiley & Sons Inc., New Jersey, 2002.

Course Code:	Advanced Computational Fluid Dynamics	Credits (L-T-P-Cr) : 4-0-0-4

Pre-requisites: Computational Fluid Dynamics

Syllabus

Finite Volume Method for complex geometries: Types of grids, Cartesian vs. curvilinear grids, Block-structured grids, Body-fitted grids in complex geometries, orthogonal grids, difficulties of curvilinear grids,
structured/unstructured/hybrid. Mapping functions: grid transformation on complex geometries, Transformation of governing equation in plane, Conservative and Nonconservative form of equations, transformation of Laplace equation, N-S equations in transformed plane, matrices and Jacobians. Unstructured grids and its discretization, discretization of diffusion and convective terms, treatment of source terms, assembly of discretized equations, Boundedness and Transportiveness, TVD Scheme, Pressurevelocity coupling in unstructured meshes. staggered vs. co-located grid arrangements. Rhie and Chow's pressure interpolation.
Accelerated CFD Methods: Advanced Numerical Techniques: Multigrid, Conjugate Iteration, and Generalised Minimal Residual (GMRES) Methods. Hardware Techniques: Introduction to PC and HPC Architecture. CPU and GPGPU parallel programming.
Multiphase Flow Modeling: Introduction: Multiphase flow classifications (separated and dispersed flows).
Examples, Challenges in modelling, Variables of interest, Fluid-particle coupling (1-way, 2-way, and 4-way coupling) Lagrange-Euler model: Discrete Phase Modelling (DPM) for particles and suspended phases. Discrete Phase Boundary conditions and its effects Discrete Element Method (DEM) Arbitrary Lagrangian and Euler (ALE) method, Immersed boundary method; Immersed interface methods, Hybrid methods Introduction to Euler-Euler model: Volume of Fluid (VoF) Method, Interface tracking & capturing methods, Level Set (LS) method, Coupled VoF-LS method, Eulerian multiphase model (EMM), Mixture (Algebraic Slip) mode (ESM), Eulerian Granular Multiphase model (EGMM) Comparison of Models and their selection
Application of CFD for modelling and simulation: Practical problem solving using CFD techniques

References

- "An Introduction to Computational Fluid Dynamics: The Finite Volume Method", H.K. Versteeg and W. Malalasekara, 2nd edition, Pearson Education, England, 2007.
- "Computational Fluid Dynamics for Engineers", B. Andersson & others, 1st edition, Cambridge University Press, U.K., 2012.
- "Using HPC For Computational Fluid Dynamics: A Guide to High Performance Computing for CFD Engineers", Shamoon Jamshed , Academic Press, 2015.
- "Computational Fluid Flow and Heat Transfer" (2nd edition), K. Muralidhar and T. Sundararajan, Narosa Publishing, 2004.
- 5. "Numerical Heat Transfer and Fluid Flow", S.V. Patankar, McGraw-Hill, New York, 1980.

B. Tech (Research): Pool-I

S No	Course Code	Subjects (Semester)	Credits (L+T+P)
1.	AM****	Advanced Biomechanics **(V)**	4-0-0
2.	AM****	Bioinstrumentation and Signal Processing **(VI)**	4-0-0
3.	AM****	Design, Innovation, and Entrepreneurship in Biomedical Engineering **(VII)**	4-0-0
4.	AM****	Elective* **(VII)**	4-0-0
		List of Electives	
1.	AM****	Artificial Intelligence in Biomedical Engineering	
2.	AM****	Biomaterials and Artificial Organs	
3.	AM****	Medical Imaging and Diagnostics	
4.	AM****	Finite Element Applications in Biomedical Engineering	
5.	AM****	Sports Biomechanics	

Course Code: AM-XXXXX	Advanced Biomechanics	Credits (L-T-P-Cr) : 4-0-0-4

Pre-requisites: Biomechanics

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	To Classify and analyze normal and pathological gait movement	2,4	Understand, Analyze
CO2	To understand how mechanics at molecular scale affects the biology at tissue and organ level	2	Understand,
CO3	To identify the structural and material properties of biological tissues and show a comprehension of the alterations brought on by load, disuse, overuse, ageing, and other variables	2	Understand,
CO4	To integrate knowledge and skills of biomechanics in other study areas of clinical applications, sports biomechanics etc.	3, 4	Analyze, Apply

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO 1	PSO2
CO1	3	2	2	2	2	1	-	-	-	2	2	1	2	1
CO2	3	3	2	1	1	2	1	1	-	2	1	1	1	2
CO3	2	1	1	2	2	2	-	-	1	1	2	1	2	1
CO4	1	2	2	2	2	3	1	1	1	1	1	1	1	2

Module	Syllabus	Hours
1.	**Kinematics:** Body Segment Parameters: Method of Measuring and Estimating Body Segment Parameters, Two Dimensional and Three-Dimensional Computational Methods. **Two-Dimensional Inverse Dynamics**: Planar Motion Analysis, Numerical Formulations, Human Joint Kinetics. Three-Dimensional Kinetics: Data Required for Three-Dimensional Analysis, Anthropometry and Three-Dimensional Kinetics Calculations	**10**
2.	**Computer Simulation of Human Movement:** Mathematical Formulations, Free Body Diagrams, Lagrange's Equation of Motion, Numerical Solution Techniques, Control Theory, Advantages and Limitation of Computer Models.	**8**
3.	**Mechanics at the Nanoscale:** Intermolecular Forces and Their Origins; Single Molecules; Thermodynamics and Statistical Mechanics, Motion at the Molecular and Macromolecular Level, Experimental Methods at the Single Molecule Level - Optical and Magnetic Traps, Force Spectroscopy, Light Scattering.	**10**
4.	**Cellular Mechanics:** Static and Dynamic Cell Processes; Cell Adhesion, Migration and Aggregation; Mechanics of Biomembranes; The Cytoskeleton and Cortex	**8**
5.	**Tissue Mechanics:** Elastic (Time Independent); Viscoelastic and Poroelastic (Time-Dependent) Behavior of Tissues; Continuum and Microstructural Models; Constitutive Laws; Electromechanical and Physicochemical Properties of Tissues; Physical Regulation of Cellular Metabolism; Experimental Methods - Macroscopic Rheology.	**6**

References

- Fung, Y. C. Biomechanics: Mechanical Properties of Living Tissues. New York, NY: Springer-Verlag, 1993.
- Nossal, R., and L. Lecar. Molecular and Cell Biophysics. Cambridge, MA: Perseus Books, 1991.
- Lodish, H., et. al. Molecular Cell Biology. New York, NY: Scientific American Books/W.H. Freeman, 1995.
- Dill, K. A., and S. Bromberg. Molecular Driving Forces. New York, NY: Routledge, 2002. ISBN: 9780815320517.
- Nihat Ozkaya and Margareta Nordin Fundamentals of Biomechanics: 3rd Edition. VNR, New York.
- David A. Winter Biomechanics and motor control of Human Movements: 3rd Edition, John Wiley & Sons, Inc.
- D. Gordon, E. Robertson, Graham E. Caldwell, Joseph Hamill Research Methods in Biomechanics: Human Kinetics

Course Code: AM-XXXXX	Biomedical Instrumentation and Signal Processing	Credits (L-T-P-Cr) : 4-0-0-4

Pre-requisites: Basics of Instrumentation and Signal Processing

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	Understand Types & Characteristics and Sources of Noises and Artifacts in Biomedical Signals.	2,4	Understand, analyze
CO2	Design of Filters for Noise and Artifact Removal from Biomedical Signals.	2	Understand,
CO3	Understand Methods for Analyzing Biomedical Signal Characteristics.	2	Understand,
CO4	Explore Alternative Techniques of Analyzing Biomedical Signals	3, 4	Analyze, apply

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	2	2	2	1	-	-	-	1	1	1	3	1
CO2	3	3	2	1	1	2	1	1	-	1	1	1	3	2
CO3	3	2	2	2	1	1	-	-	1	1	2	1	2	2
CO4	3	2	2	2	1	1	1	1	1	1	1	1	2	2

Module	Syllabus	Hours
1.	Basic Concepts of Medical Instrumentation: Generalized Medical Instrumentation System, Measurement Constraints, Classifications, Static and Dynamic Characteristics, Design Criteria, Medical Instrumentation Development Process, Regulation of Medical Devices.	**8**
2.	**Theory, Analysis and Design of Biomedical Transducers:** Optical, Photo-Electric, Electrochemical, Electrical, Mechanical, Electromechanical and Thermoelectric, Applications to Biomedical Systems, Transducer Characteristics Sensors for Physical Measurands, Sensors for Measurement of Chemicals.	**8**
3.	**Medical Measurand Sensor**: Characteristics and Design for Measurement of Medical Parameters like ECG, Arterial Blood Pressure Heart Sounds, Bio-Potential Amplifiers, Various Types of Electrodes used in ECG, EEG And EMG, Measurement Of EEG, EMG and Their Diagnostic Applications in Medicine, Flow and Pressure Measuring Instruments in Biomedical Engineering, Medical Ultrasonography, Pulse Oximeter, Defibrillators, Foetal ECG.	**8**
4.	**Introduction to Bioelectric Phenomenon:** Generation, Transmission and Interaction of Signals in Nervous Systems. Discussion of Initiation and Propagation of Action Potential along the Nerve Fibres. Voltage Clamp Experiments, Synaptic Transmission and Transduction Process and Receptors. Frequency Modulation of the Electrical Signals. **Mathematical Models:** Electrical Circuits Models and Describing Behaviour of Cell Membrane. Neural Control Mechanism, Genesis and Characteristics Of EEG, ECG, EMG And Evoked Potentials.	**10**
5.	**Removal of Noise and Artifacts from Biomedical Signal:** Random and Structured Noise, Physiological Interference, Stationary and Nonstationary Processes, Noises and Artifacts Present in ECG, Time and Frequency Domain Filtering.	**8**

References

Khandpur R.S., Hand book of Biomedical instrumentation, TMH.
Rangayyan, R.M., 2015. Biomedical signal analysis (Vol. 33). John Wiley & Sons.
Reddy, D.C., 2005. Biomedical signal processing: principles and techniques. McGraw-Hill
Tompkins, W.J., 1993. Biomedical digital signal processing. Editorial Prentice Hall.
Sörnmo, L. and Laguna, P., 2005. Bioelectrical signal processing in cardiac and neurological applications (Vol. 8). Academic Press.

Course Code: AM-XXXXX	Design, Innovation, and Entrepreneurship in Biomedical Engineering	Credits (L-T-P-Cr) : 3-0-0-3

Pre-requisites: Advanced Biomechanics

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	Design and develop devices for biomedical application.	2,4	Understand, Analyze
CO2	Provide innovative solutions for healthcare problems	2,3	Understand, Apply
CO3	Inculcate Entrepreneurship abilities in the area of healthcare.	4	Analyze
CO4	Develop leadership skill in the area of biomedical engineering entrepreneurship.	3, 4	Apply

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO 1	PO 2	PO 3	PO 4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	2	2	2	1	-	-	-	1	1	1	3	1
CO2	3	3	2	1	1	2	1	1	-	1	1	1	3	2
CO3	3	2	2	2	1	1	-	-	1	1	2	1	2	2
CO4	3	2	2	2	1	1	1	1	1	1	1	1	2	2

Module	Syllabus	Hours
1.	**Design Process:** Creative and Design Thinking, Minimum Viable Product, Business Model Development, Business Plan and Access to Funding. Elements Of Design Process Including Need Identification, Concept Generation, Concept Selection and Implementation with Specific Applications in Healthcare. System Synthesis, Design Analyses, Optimization, Impact on Patient Health and Comfort, Healthcare Costs, Clinical Trials and Regulatory Issues And Medical Ethics.	**10**
2.	**Orthopedic Implant Design:** Design Concepts, Clinical Problems Requiring Orthopedic Implants for Solution, Principles of Orthopedic Implant Design, Design Parameters.	**8**
3.	**Tissue Engineering:** Scaffolds, Cells and Regulators, Case Study of Organ Regeneration, Design Parameters, Design Specifications: Biomaterials, Biocompatibility: Local and Systemic Effects, Design Specifications, Biocompatibility: Scar Formation and Contraction, Degradation of Devices: Corrosion and Wear, Regulation of Medical Devices	**10**
4.	**Cardiovascular Prostheses Design:** Heart Valves and Stents, Devices for Nerve Regeneration, Musculoskeletal Soft Tissues: Meniscus, Intervertebral Disk, Dental and Ear Implants. Design and Application of Electromechanical Biomedical Devices, Concept of Prototype Development and Testing of Medical Instrument.	**10**
5.	**Innovations in Healthcare:** Idea generation, market research, product development and financing, Team development and business model for commercialization of healthcare innovations. **Introduction to entrepreneurship:** Healthcare start- ups. Recent Innovations in Healthcare.	**8**

References

- E. J. Mccormick, Human factors in Engineering and Design, TMH.
- O. P. Astrand and R. Kaare, Textbook of Work Physiology, McGraw Hill.
- Yannas, I. V. *Tissue and Organ Regeneration in Adults*. New York, NY: Springer-Verlag, 2001.
- Ayyana M. Chakravartula, Lisa A. Pruitt Mechanics of Biomaterials: Fundamental Principles for Implant Design (Cambridge Texts in Biomedical Engineering).
- Webster J. G., *Medical Instrumentation: Application and Design*, 4th ed., John Wiley & Sons: New York.
- J. D. Branzino, Handbook of Biomedical Engineering: Fundamentals of Biomedical Engineering, CRC Press.
- Measuring the Gains from Medical Research by Kevin Murphy and Robert Topel, Published by the University of Chicago Press
- Medical Care Output and Productivity by Ernst Berndt and David Cutler, National Bureau of Economic Research, Studies in Income and Wealth Volume 62
- Craig R. Davis “Calculated Risk: A Framework for Evaluating Product Development.

Course Code: AM-XXXXX	Finite Element Analysis in Biomedical Engineering	Credits (L-T-P-Cr) : 4-0-0-4

Pre-requisites: Advanced Biomechanics, Finite Element Methods

Course Outcome

S. No.	Outcomes	BT Level	BT Description
CO1	To identify the dimension, variables involved, constrains to be imposed and type of element(s) to be used for finite element analysis.	2	Understand
CO2	To formulate, program, and solve a solid mechanics problem application in biomedical engineering.	2,3	Understand, Apply
CO3	To analyze, interpret and communicate results obtained from developed computer program or commercial finite element software.	4	Analyze
CO4	To pursue higher /self-study and research, involving finite element analysis in the domain of solid mechanics application in biomedical engineering.	3, 4	Apply

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	2	1	-	-	-	2	1	1	2	1
CO2	3	3	3	3	1	2	1	1	-	1	1	1	2	2
CO3	2	3	2	1	2	2	-	-	1	2	2	1	2	1
CO4	3	2	2	1	1	1	1	1	1	1	1	1	2	1

Module	Syllabus	Hours
1.	**The Finite Element and Finite Difference Methods:** Gallerkin, Weighted Residuals, Discretization,	6
2.	**Mechanical Analysis of Structures:** Truss Systems, Beam Systems, 2D Solids, Meshing, Organ Level Analysis of Bones, DOFs, Hand Calculations of Simple FE problems, Underlying PDEs Micro- and multi-scale analysis, voxel models, solver limitations, large scale solver	8
3.	**Contact Analysis:** Friction, Bonding, Rough Contact, Implants, Bone-Cement Composites, pushout tests **Flow in Porous Media:** Potential problems, Terzaghi's consolidation, Confined and unconfined compression of cartilage	8
4.	**Heat Transfer and Mass Transport:** Diffusion, Conduction and Convection, Equivalency of Equations, Heat Transfer and Mass Transport, Sequentially-Coupled Poroelastic and Transport Models for Solute Transport **Computational Biofluid Dynamics:** Newtonian vs. Non-Newtonian fluid, potential flow	10
5.	**Application through Computer Programming & Commercial Software:** Input for Geometric & Material Configuration, Loading and Boundary Conditions, Automatic Mesh Generation, Nodal Coordinate and Nodal Connectivity, Calculation of Element Matrices (Stiffness & Mass Matrices, Load Vector), Assembly of Element Matrices to Global Matrices, Imposing Boundary Conditions, Solution (Gauss Elimination & other methods), and Post Processing.	10

References

- Energy and Finite Element Methods in Structural Mechanics: I. H. Shames and C. L. Dym.
- Concepts and Applications of Finite Element Analysis: R. D. Cook, D. S. Malkus and M. E. Plesha.
- The Finite Element Method Vol. I-II: O.C. Zienkiwiczand R.L. Taylor.
- Finite Element Procedures: K. J. Bathe.
- An Introduction to Finite Element Methods: J.N. Reddy.
- Finite Element Methods in Engineering: S.S. Rao.
- Yang, Z. C. (2019). Finite Element Analysis for Biomedical Engineering Applications. CRC Press.

Course Code: AM-XXXXX	Medical Imaging and Diagnostics	Credits (L-T-P-Cr) : 4-0-0-4
Pre-requisites: Digital image processing		

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Describe the physics principles underlying the operation of medical imaging equipment, including X-ray, CT, MRI, and nuclear imaging systems.	2	Understand
CO2	Apply mathematical methods of image construction and processing in the context of different medical imaging modalities.	2, 4	Understand, Analyse
CO3	Demonstrate an understanding of the clinical applications and relevance of various imaging methods in healthcare.	2, 4	Understand, Analyse
CO4	Discuss radiation safety issues related to the operation of medical imaging equipment and implement appropriate safety measures in practice.	2, 4	Understand, Analyse

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	3	2	2	2	-	-	-	2	1	1	3	3
CO2	2	2	3	2	1	1	1	1	-	2	1	1	2	2
CO3	2	2	3	1	2	1	-	-	1	2	2	1	3	2
CO4	2	2	2	1	1	2	1	1	1	2	1	1	2	2

Module	Syllabus	Hours
1	**Medical X-Ray Equipment:** Nature of X-rays and X-ray absorption, Tissue contrast in X-ray imaging X-ray equipment block diagram, X-ray tube, collimator, Bucky grid, and power supply **Digital radiography:** discrete digital detectors, storage phosphor, and film scanning. **Fluoroscopy:** X-ray image intensifier tubes, digital fluoroscopy. **Angiography:** cine angiography, digital subtraction angiography, Mammography.	**08**
2	**Computed Tomography:** Principles of tomography, CT generations: X-ray sources, collimation, X-ray detectors, viewing systems, Spiral CT scanning and ultra-fast CT scanners.	**09**
3	**Magnetic Resonance Imaging:** Fundamentals of magnetic resonance imaging, Interaction of nuclei with static magnetic field and radiofrequency wave, Rotation and precession of nuclei. **Induction of magnetic resonance signals:** bulk magnetization, relaxation processes (T1 and T2). Block diagram approach of MRI system, System magnet (permanent, electromagnet, and superconductors). Gradient magnetic fields, radiofrequency coils (sending and receiving), shim coils, electronic components. Functional MRI (fMRI).	**12**
4	**Nuclear Imaging System: Radioisotopes:** alpha, beta, and gamma radiations, Radiopharmaceuticals Radiation. **Detectors:** gas-filled, ionization chambers, proportional counter, GM counter, and scintillation detectors. **Gamma camera:** principle of operation, collimator, photomultiplier tube, X-Y positioning circuit, pulse height analyser. Principles of single-photon emission computed tomography (SPECT) and positron emission tomography (PET)	**10**
5	**Radiation Therapy and Radiation Safety: Effects of radiation:** direct and indirect. **Radiation therapy:** linear accelerator, tele gamma machine. **Radiation measuring instruments**: dosimeter, film badges, thermo-luminescent dosimeters, electronic dosimeter. Radiation protection in medicine	**09**

References

- William R. Hendee, E. Russell Ritenour, Medical Imaging Physics.
- Jerry L. Prince, Jonathan M., Medical Imaging Signals and Systems. Pearson Education.
- Andrew G. Webb, Introduction to Biomedical Imaging, IEEE Press.
- R.Hendee and Russell Ritenour, Medical Imaging Physics, William,Wiley- Liss.

Course Code: AM-XXXXX	Biomaterials and Artificial Organs	Credits (L-T-P-Cr): 4-0-0-4

Pre-requisites: Basic knowledge of biology and physiology, Material science or engineering background

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Understand the properties and characteristics of biomaterials and their applications in medicine.	2	Understand
CO2	Analyse the interactions between biomaterials and biological systems.	2, 4	Understand, Analyse
CO3	Evaluate the design and fabrication methods for artificial organs.	2, 4	Understand, Analyse
CO4	Discuss the challenges and ethical considerations in the development of artificial organs.	2, 4	Understand, Analyse
CO5	Identify emerging trends and future directions in the field of biomaterials and artificial organs.	2, 3	Understand, Apply

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	2	3	2	2	-	-	-	3	1	1	3	3
CO2	3	2	3	2	2	1	2	1	-	2	1	1	2	2
CO3	3	3	2	2	2	1	-	-	1	1	2	1	3	2
CO4	3	2	2	2	2	2	2	1	1	1	1	1	2	2
CO5	2	1	2	1	3	2	3	1	-	1	2	1	1	3

Module	Syllabus	Hours
1	**Introduction to Biomaterials:** Definition and classification of biomaterials, Properties of biomaterials (mechanical, chemical, biological), Applications of biomaterials in medicine, Selection criteria for biomaterials, Examples of biomaterials used in medical devices. **Biocompatibility and Host Response:** Definition and importance of biocompatibility, Host response to biomaterials (acute and chronic inflammation, fibrosis, foreign body reaction), Factors affecting biocompatibility (surface properties, degradation rate, immunogenicity), In vitro and in vivo biocompatibility testing methods, Strategies to improve biocompatibility	08
2	**Tissue Engineering:** Definition and principles of tissue engineering, Scaffold-based tissue engineering techniques (porous scaffolds, electrospinning, 3D printing), Scaffold-free tissue engineering techniques (cell sheet engineering, self-assembly), Cell sourcing for tissue engineering, Vascularization and innervation of engineered tissues	08
3	**Design of Artificial Organs:** Definition and examples of artificial organs, Design criteria for artificial organs (biocompatibility, mechanical properties, functional performance), Heart assist devices (ventricular assist devices, total artificial hearts), Kidney replacement devices (hemodialysis, peritoneal dialysis, renal replacement therapy), Liver assist devices (bioartificial liver, extracorporeal liver support), Lung assist devices (extracorporeal membrane oxygenation, artificial lung)	11
4	**Regulatory Requirements for Medical Devices:** Overview of medical device regulations (FDA, European Union, other regulatory bodies), Classification of medical devices (Class I, II, III), Preclinical testing and evaluation (biocompatibility, safety, efficacy), Clinical trials (phases, design, endpoints), Post-market surveillance (adverse event reporting, device tracking, recalls)	09
5	**Case Studies and Applications of Biomaterials and Artificial Organs:** Orthopedic implants (joint replacements, bone grafts, spinal implants), Cardiovascular devices (stents, heart valves, pacemakers, defibrillators), Neural prostheses (cochlear implants, retinal implants, brain-computer interfaces), Ethical and social issues related to biomaterials and artificial organs, Future directions and emerging technologies in biomaterials and artificial organs.	12

References

- Biomaterials Science: An Introduction to Materials in Medicine by Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, and Jack E. Lemons, Academic Press.
- Tissue Engineering: Principles and Applications by Bernhard Palsson, Jeffrey A. Hubbell, Robert Plonsey, Joseph D. Bronzino, CRC Press
- Artificial Organs by Joseph D. Bronzino, CRC/Taylor & Francis.
- Regulatory Affairs for Biomaterials and Medical Devices by Stephen F. Amato and Richard A. Endres, Woodhead Publishing.

Course Code: AM-XXXXX	Artificial Intelligence in Biomedical Engineering	Credits (L-T-P-Cr) : 4-0-0-4

Pre-requisites: Basic knowledge of biology and physiology, AI and ML

Course Outcome

S.No.	Outcomes	BT Level	BT Description
CO1	Students will be able to explain the basic principles of artificial intelligence and its applications in biomedical engineering.	2	Understand
CO2	Students will be able to apply machine learning and deep learning algorithms to biomedical engineering problems.	2, 4	Understand, Analyse
CO3	Students will be able to use natural language processing tools to extract information from medical texts and electronic health records.	2, 4	Understand, Analyse
CO4	Students will be able to design and implement robotic systems for medical applications.	2, 4	Understand, Analyse
CO5	Students will be able to analyze the ethical and social implications of using artificial intelligence in healthcare.	2, 4	Understand, Analyse
CO6	Students will be able to identify emerging trends and future directions in artificial intelligence and biomedical engineering.	2, 3	Understand, Apply

Articulation Matrix: (CO-PO-PSO Mapping)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	3	2	1	1	-	-	-	2	2	2	2	2
CO2	3	2	2	2	1	1	1	2	-	1	1	1	2	1
CO3	3	2	3	2	2	1	-	-	1	1	2	2	2	1
CO4	3	2	3	2	1	1	1	1	1	1	1	1	1	1
CO5	3	3	3	2	2	2	1	1	-	1	2	2	2	2
CO6	3	3	2	2	2	2	2	2	1	2	2	1	2	2

Module	Syllabus	Hours
1	**Introduction to Artificial Intelligence in Biomedical Engineering:** Definition and history of artificial intelligence, Applications of artificial intelligence in biomedical engineering, Types of artificial intelligence (machine learning, deep learning, natural language processing, robotics), Advantages and challenges of using artificial intelligence in biomedical engineering	08
2	**Machine Learning in Biomedical Engineering:** Definition and types of machine learning (supervised, unsupervised, reinforcement), Data pre-processing and feature extraction, Machine learning algorithms (decision trees, support vector machines, neural networks), Applications of machine learning in biomedical engineering (diagnosis, prognosis, drug discovery).	08
3	**Deep Learning in Biomedical Engineering:** Definition and types of deep learning (convolutional neural networks, recurrent neural networks, generative adversarial networks), Training deep learning models (backpropagation, gradient descent), Applications of deep learning in biomedical engineering (image analysis, signal processing, natural language processing)	08
4	**Natural Language Processing in Biomedical Engineering:** Definition and applications of natural language processing (text mining, information extraction, sentiment analysis), Challenges of natural language processing in biomedical engineering (medical terminology, accuracy, privacy), Applications of natural language processing in biomedical engineering (clinical decision support, drug discovery, patient monitoring). **Robotics in Biomedical Engineering:** Definition and types of robotics (surgical robots, exoskeletons, prosthetics), Control systems for robotics (PID, fuzzy logic, adaptive control), Applications of robotics in biomedical engineering (surgery, rehabilitation, assistive devices)	12
5	**Future Directions and Emerging Technologies in Artificial Intelligence in Biomedical Engineering:** Integration of artificial intelligence with other technologies (Internet of Things, blockchain, cloud computing), Personalized medicine and precision healthcare, Augmented and virtual reality in biomedical engineering, Brain-computer interfaces and neural engineering.	12

References

1. Artificial Intelligence in Healthcare by Adam Bohr and Matthias R. Becker, Academic Press.
2. Handbook of Artificial Intelligence in Biomedical Engineering by Krishnan Saravanan, Ramesh Kesavan, S. Balamurugan, G. S. Mahalakshmi, CRC Press.
3. Handbook Artificial Intelligence in Medicine by Lei Xing and A. K. Louis.
4. Deep Learning for Medical Image Analysis by S. Kevin Zhou, Hayit Greenspan, and Dinggang Shen.