Scheme of Examination and Syllabi of course work for

DOCTOR OF PHILOSOPHY

in

Faculty of Engineering & Technology

Mechanical Engineering

(Academic Session **2025–2026)**

PANJAB UNIVERSITY, CHANDIGARH

SCHEME OF EXAMINATION AND SYLLABI OF Ph.D. COURSE WORK

MECHANICAL ENGINEERING

ACADEMIC SESSION 2025-26

S. no	Paper No.	Paper Title	L	T	P	Total	Credits	Marks (Int. Exam)	Marks (Univ. Exam)
1	**RM-9001**	**Research Methodology**	4	-	-	4	4	50	50
2	**RS-9002**	**Research and Publication Ethics**	4	-	-	4	4	50	50
3	**—---**	**Department Elective** (Mechanical Engineering)	4	-	-	4	4	50	50

Research Scholars joining PhD in Faculty of Engineering after B.E./B.Tech are required to study two extra courses to earn a total of 20 credits. These research scholars cannot take ME9207 as Department Elective. The extra subjects are as follows:

S. no	Paper No.	Paper Title	L	T	P	Total	Credits	Marks (Int. Exam)	Marks (Univ. Exam)
1	**ME9207**	**Design of Experiments**	**4**	**-**	**-**	**4**	**4**	**50**	**50**
2	**-----**	**Department Elective** (Mechanical Engineering) **OR** **/Department Elective** (from Allied branches across Faculty of Engineering)	**4**	**-**	**-**	**4**	**4**	**50**	**50**

DEPARTMENT ELECTIVE
(Mechanical Engineering)

S.No.	Paper No./code	Paper Title
1	ME9201	Advance Heat Transfer
2	ME9202	Non-Conventional Machining
3	ME9203	Continuum Mechanics
4	ME9204	Finite Element Methods
5	ME9205	Composite Materials
6	ME9206	Optimization Techniques
7	ME9207	Design of Experiments
8	ME9208	Material Characterization
9	ME9209	Additive Manufacturing
10	ME9210	Machine Learning
11	ME9211	Introduction to Numerical Methods
12	ME9212	Mechanics of Solids
13#	MME103	Advanced Mechanics of Materials
14#	MME201	Continuum Mechanics
15#	MME202	Advanced Manufacturing Processes
16#	MME203	Advances in Engineering Materials
17#	MME204	Structural Dynamics
18#	MME301	Advanced Machine Design

courses common with M.E. Mechanical Engineering

*Guidelines for Course Work:

The one semester Course Work of minimum 140 teaching hours would comprise four papers out of which one should be related to Research Methodology (of 35 teaching hours)

Research Scholars joining PhD in Faculty of Engineering after B.E./B.Tech are required to study two extra courses (of 4 credits each) to earn a total of 20 credits.
The components of Continuous Evaluation/ Examination would be as under:

(a) Continuous Evaluation (Book reviews, Term Paper and its presentation, Seminar, etc.)	: 50 marks
(b) End Examination	: 50 marks
(c) Pass percentage in each paper (i) & (ii) together)	: 55%

A candidate who passes will be given 'S' grade i.e. satisfactory completion or else 'X' grade i.e. Unsatisfactory.

Further:

(i) A candidate would be required to attend minimum of 75% of the lecturers delivered/activity undertaken;

(ii) If a candidate has passed at least three papers and is unable to pass the 4^{th} paper due to one reason or the other, he/she be allowed to appear in that paper in the next examination, provided he/she had attended the 75% of the lectures delivered;

(iii) If a candidate is unable to appear in any paper/papers due to the circumstances beyond his/ her control. He/ she be allowed to appear in that paper/ those papers in the next examination, provided he/she had attended the 75% of the lectures delivered;

(iv) If a candidate fails to earn 12 credits he/ she be asked to do the entire course work again;

(v) The End Examination paper will consist of 5 questions and candidate will have to attempt all the questions; and

(vi) A Research Advisory Committee (RAC) will be constituted for every Ph.D student for continuous monitoring of students' performance. The student will have to present his/ her progress report after every 6 months before the RAC.

Paper Title: Research Methodology

Paper Code: RM-9001

L	T	P
4	**0**	**0**

1. **Foundation of Research:** Meaning, Objectives, Motivation, Utility. Distinct Approaches: Descriptive Research vs. Analytical Research, Applied Research vs. Fundamental Research, Quantitative vs. Qualitative, Conceptual vs. Experimental (or Empirical), Significance of Research. Characteristics of scientific method.Understanding the language of research – Concept, Construct, Definition, Variable. Research Methodology versus Research Methods. (8)

2. **Research Design:** Problem Identification & Formulation, extensive literature survey, Need of a research design, Different Research Designs, Experimental Research Design: Concept of Independent & Dependent variables,decision variables, input variables, state variables, extraneous variables, random variables and output variables. Measurements based research methods, Deductive and Inductive methods, Concept of causality, determinism, generalization, replication. Problems in measurement in research, Validity and Reliability. Levels of measurement: Nominal, Ordinal, Interval, Ratio. (10)

3. **Statistical Tools In Research:** Statistics in Engineering, Methods to search required information effectively, Scientific and Academic Databases, Data Preparation and analysis: Mean, range, mode, median, standard deviation, characteristics of Normal distribution, Measures of central tendency and dispersion, Developing Hypothesis, Steps of Hypothesis Testing: Logic and Importance, choice of a statistical test,t-test, p-value, ANOVA (one-way)and Chi-square test. (10)

4. **Introduction to Modeling and Simulation:** Definition of Modeling, Design of Basic Engineering Systems in Mechanical and Electrical domain, Types of Models: Physical, Mathematical, Static, Dynamic, Numerical, Analytical. Modeling Principles: Block-Building, Aggregation, Relevance, Accuracy, System Viewpoint to Modeling, Concept of Modeling of Dynamic Systems, Simulation Definition, Introduction to System Simulation, Experimental Nature of Simulation, Simulation Types: Continuous and Discrete, Simulation Process Steps. (10)

5. **Research Reporting and Publication:**Structure and components of scientific reports, Types of report, Technical reports and thesis, Layout of a Research Paper, Impact factor of Journals, Metrics: h-index, Open access,Plagiarism and Self-Plagiarism, Software for detection of Plagiarism, Predatory publishers and journals. (7)

Reference Books:

1. C.R. Kothari, “Research Methodology – Methods and Techniques”, Wiley Eastern Ltd 2009

2. Richard I. Levin, David S. Rubin, Statistics for Management (7th Edition), Pearson Education India.

3. Geoffrey Gordon, “System Simulation”, Prentice Hall of India.

4. K. N. Krishnaswamy, AppaIyerSivakumar, M. Mathirajan," Management Research Methodology: Integration of Methods and Techniques, Pearson, 2006

5. Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers, Keying Ye," Probability and Statistics for Engineers and Scientists (International Edition)", Pearson Edition, 2002

6. Statistics in Research, BernandOstle and Richard N.Mensing 3rd ed, 1975, Oxford & IBH Pub Co.

7. Probability and Statistics in Engineering, Hines, Montgomery, Goldsman and Borror, 4th ed, 2003, John Wiley & Sons

8. Modeling and Simulation of Dynamic Systems NPTEL lecture Notes (L1 to L4) by Prof. Pushparaj Mani Pathak, IIT Roorkee

Paper Title: Research and Publication Ethics

Paper Code: RS-9002

L	T	P
4	**0**	**0**

Objectives: This course has total 6 units focusing on basics of philosophy of science and ethics, research integrity, publication ethics. Hands on sessions are designed to identify research misconduct and predatory publications. Indexing and citation databases, open access publications, research metrics (citations, h-index, Impact factor etc.) and plagiarism tools will be introduced in this course.

Syllabus

RPE 01: Philosophy and Ethics (3 hrs)

1. Introduction to philosophy: definition, nature and scope, concept, branches
2. Ethics: definition, moral philosophy, nature of moral judgements and reactions

RPE 02: Scientific Conduct (5 hrs)

1. Ethics with respect to science and research
2. Intellectual honest and research integrity
3. Scientific misconducts: falsification, fabrication, and plagiarism.
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data.

RPE 03: Publication Ethics (7 hrs)

1. Publication ethics: definition, introduction and importance
2. Best practices/standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice verse, types
5. Violation of publication ethics, authorship and contributor ship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

PRACTICE

RPE 04: Open Access Publishing (4 hrs)

1. Open access publications and initiatives
2. SHERPA/RoMEO online resource to check publisher copyright and self-archiving policies
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder/ journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

RPE 05: Publication Misconduct (4 hrs)

A. Group Discussions (2 hrs)

1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools (2 hrs)

Use of plagiarism software like Turnitin, Urkund and other open source software tools

RPE 06: Databases and Research Metrics (7 hrs)

A. Databases (4 hrs)

1. Indexing databases
2. Citation databases: Web of Science, Scopus, etc.

B. Research Metrics (3 hrs)

1. Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score
2. Metrics: h-index, g index, i10 index, altmetrics

References:

1. A Bird, "Philosophy of Science", Routledge 2006.
2. Alasdair MacIntyre, "A Short History of Ethics", London 1967.
3. P. Chaddah, "Ethics in Competitive Research: Do not get Scooped; do not get plagiarized", 2018, ISBN: 978-9387480865.
4. National Academy of Sciences, "On being a scientist: A guide to responsible conduct in research", third edition, National Academic Press, 2009.
5. D. B. Resnik, "What is ethics in research & why is t important", National Institute of Environmental Health Science, 1-10, Nature 489 (7415), 179-179
6. Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance, 2019, ISBM: 978-81-939482, 1-7.

DEPARTMENT ELECTIVE
(Mechanical Engineering)

Paper Title: Advance Heat Transfer

Paper Code: ME9201

L	T	P
4	0	0

Conduction: Steady state heat conduction including heat generation and heat losses in different co-ordinates, numerical analogue and graphical methods. Unsteady state heat conduction as applied to thick wall, cylinder and sphere with sudden and with periodic changes of surface temperature. Semi-infinite state with imposed wall temperature distribution. Heat conduction with moving boundaries numerical analogue and graphical methods.

Conductive Heat Transfer: Fundamentals: Reynolds transport theorem. Derivation of N.S equation and energy; Dimensionless Number.

Convection: Laminar duct flows: Convection in fully developed flow and developing flow. Effect of wall boundary condition. Natural Convection: External flows; boundary laying integral similarity solution; Exact & empirical correlation, Heat transfer over plane plate, cylinders, tube banks and spheres. Turbulent Flows: Fundamental of Turbulent Heat convection; turbulent boundary layer; Exact & empirical correlations.

Radiation: Law of Radiation, shape factor Algebra, Radiative heat exchange between different surfaces of simple geometric shape. Use of electrical analysis in solving problem of Radiative heat exchange. Combined effect of heat transfer due to conduction, convection and radiation, use of relaxation methods.

Text Books:

1. Incropera & Dewtt," Heat & Mass Transfer", John Willey Ltd.
2. J.P. Holman," Heat Transfer", TMH
3. R.C. Sachdeva," Heat & Mass Transfer", New Age

Paper Title: Non-Conventional Machining

Paper Code: ME9202

L	T	P
4	0	0

Introduction: Classification, Advantages & limitations of non-conventional machining, Hybrid Machining, Ultrasonic machining (USM)-Principle of operation, process details, applications and advantages, limitations of USM.

Abrasive and Water Jet Machining: Basic principle, mechanism of material removal, working principle of Abrasive jet machining (AJM), water jet machining (WJM), merits & demerits, application.

Chemical Machining (CM): Working principle, process characteristics, procedures, advantages & disadvantages of chemical machining.

Electrochemical Processes: Fundamentals, details of machining setup, materials and selection of tools, applications, Concept of others processes like ECG, Electrochemical deburring etc.

Thermal Metal Removal Processes: Working principles, Mechanism of material removal, process parameters, advantages & limitations, applications of processes like electric discharge machining(EDM), Electron Beam Machining (EBM), Ion beam machining (IBM), Plasma arc machining (PAM), Laser beam machining(LBM).

Books:

1. V K Jain," Advanced Machining Processes," Allied
2. Benedict," Unconventional Machining Methods", McH
3. HMT ,"Production Technology," TMH
4. M. Adithan,"Non Convectional Machining," John Wiley
5. P.K. Mishra," Non-Conventional Machining", Narosa Publications
6. Shan & Pandey," Modern machining process", TMH

Paper Title: Continuum Mechanics **L T P**
Paper Code: ME9203 **4 0 0**

Introduction: What is a Continuum?

Mathematical Preliminaries: Euclidean Space; Tensor Algebra; Eigenvalues, Eigenvectors, Polar Decomposition, Invariants; Higher Order Tensors; Tensor Calculus; Curvilinear Coordinates.

Kinematics: Body, Configuration, Motion, Displacement; Material Derivative, Velocity, Acceleration; Deformation and Strain; Velocity Gradient, Rate of Deformation Tensor, Vorticity Tensor; Material Point, Material Line, Material Surface, Material Volume; Volume Elements and Surface Elements in Volume and Surface Integrations.

Fundamental Laws of Thermomechanics: Mass; Forces and Moments, Linear and Angular Momentum; Equations of Motion; The First Law of Thermodynamics; The Transport and Localization Theorems; Cauchy Stress Tensor, Heat Flux Vector; Energy Theorem and Stress Power; Local forms of the Conservation Laws; Lagrangian forms of the Conservation Laws; Piola-Kirchhoff Stress Tensors, Referential Heat Flux Vector; Lagrangian form of the Energy Theorem; Local Conservation Laws in Lagrangian form; The Second Law of Thermodynamics.

Constitutive Modeling in Mechanics and Thermomechanics: Fundamental Laws, Constitutive Equations, A Well-posed Initial-value Boundary-value Problem; Restrictions on Constitutive Equations; Fundamental Laws, Constitutive Equations, Thermomechanical Processes; Restrictions on the Constitutive Equations.

Nonlinear Elasticity: Mechanical Theory; Thermomechanical Theory; Strain Energy Models.

Fluid Mechanics: Mechanical Theory; Thermomechanical Theory.

Incompressibility and Thermal Expansion: Newtonian Fluids; Nonlinear Elastic Solids;

Thermo-Electro-Magneto-Mechanical Behavior: Integral and Point wise forms of Fundamental Laws of Continuum Electrodynamics; Modeling of Effective Electromagnetic Fields; Modeling of Electromagnetically Induced Coupling Terms; Thermo-Electro-Magneto-Mechanical Process; Large and Small Deformation Theory of Thermo-Electro-Magneto-Elastic Materials; Specialization of Small Deformation Framework to Piezoelectric Materials.

Textbooks:

1. Fundamentals of Continuum Mechanics: With Applications to Mechanical, Thermomechanical, and Smart Materials by Stephen Bechtel and Robert Lowe, Academic Press.
2. Continuum Mechanics: Concise Theory and Problems by P. Chadwick, Dover Publications.
3. Introduction to Continuum Mechanics by W. Michael Lai, Erhard Krempl, David H. Rubin, Butterworth-Heinemann Publishers.

4. Continuum Mechanics for Engineers by G. Thomas Mase, Ronald E. Smelser, Jenn Stroud Rossmann, CRC Press.
5. The Mechanics and Thermodynamics of Continua by Morton E. Gurtin, Eliot Fried, Lallit Anand, Cambridge University Press.
6. Introduction to the Mechanics of a Continuous Medium by Lawrence E. Malvern, Pearson.

Paper Title: Finite Element Methods

Paper Code: ME9204

L	T	P
4	0	0

Introduction& Fundamental Concepts: Historical Background, Stresses and equilibrium, Boundary Conditions, Strain-Displacement Relations, Stress-Strain Relations, Temperature Effects, Vectors and Matrices. Classification of Differential Equations, Rayleigh-Ritz Method, Galerkin's Method, Point Collocation Method, Least Square Method, Weighted Residual Method, Variational Formulation.

1-D FE Modeling: Finite Element Modeling, Coordinates and Shape Functions, Generalized Coordinates, Natural Coordinates in 1D, 2D and 3D, Coordinate Transformation, Assembly of Global Stiffness matrix and Load vector, Properties of Stiffness Matrix, Treatment of Boundary Conditions and Temperature Effects. Truss and Beam Elements.

2-D FE Modeling: Finite Element Modeling, Constant Strain Triangle (CST)

3-D FE Modeling: The Four Node Quadrilateral, Numerical Integration, Higher Order Elements; Nine Node Quadrilateral, Eight Node Quadrilaterals, Six Node Triangle

Truss: Introduction, Plane Trusses, Assembly of Global Stiffness Matrix and load vector

Higher-Order Elements: Plate Bending, C0 and C1 Elements, Non-conforming Elements and Patch Test

Scalar Field Problems: Introduction, Steady-state heat transfer, Potential Flow, Fluid Flow in Ducts

Dynamic Considerations: Element Mass Matrices, Evaluation of Eigen Values and Eigen Vectors. (Introduction only)

Computer Implementation: Introduction; Computer Program Organization for Calculation of System Matrices

Books:

1. Chandrupatla and Belegundu,"Introduction to Finite Elements in Engineering", PHI
2. Bathe," Finite Element Procedures," PHI
3. Reddy,"An Introduction to Finite Element Method," TMH
4. Huebner," The Finite Element Methods for Engineers," John Wiley
5. Zienkiewicz ,"The Finite Element Method", TMH
6. Buchanan," Finite Element Analysis", McGraw Hill

Paper Title: Composite Materials

Paper Code: ME9205

L	T	P
4	0	0

Introduction: General introduction to composites; historical background; concept of matrix and reinforcement and particulates.

Matrix and reinforcement: Types of matrix and reinforcement, volume fraction and weight fraction Fiber architecture fiber packing arrangements, whiskers.

Fabrication methods of polymer composites: Liquid resin impregnated routes, pressurized consolidation of resin pre-pegs, consolidation of resin molding compounds, injection molding of thermoplastics, hot press molding of thermoplastics

Fabrication of ceramic composites: Powder based routes, reactive processing, layered ceramic composites, carbon/carbon composites

Fabrication routes of metal matrix composites: Squeeze infiltration, stir casting, spray deposition, powder blending and consolidation, diffusion bonding of foils, PVD.

Testing and characterization: Different tests like internal stress measurement by diffraction, metallographic preparation etc with special emphasis to metal matrix composites

Secondary processing and application of composites: Secondary processing like machining, joining, extrusion of composites; Application and case studies

Books:

1. S.C. Sharma," Composite materials", Narosa Publishers
2. R.K. Everret & R.J. Arsenault," Metal matrix composite", Academic press
3. Introduction to metal Matrix Composite

Paper Title: Optimization Techniques

Paper Code: ME9206

L	T	P
4	0	0

Objectives: This course will provide the students with good understanding of various optimization techniques used in engineering applications. At the end of this course, students will be having good knowledge of optimization techniques, their concept and applications.

Numerical Techniques: Introduction to numerical techniques, Numerical differentiation and numerical integration, Eigen value problems, Newton-Raphson's method, Computer based numerical analysis.

Introduction to Optimization: Introduction and Engineering applications of optimization, Optimal Problem Formulation; Design –variables, Constraints, Objective function, Variable bounds.

Single-variable Optimization: Optimality Criteria, Bracketing Methods – Exhaustive search and Bounding phase methods, Region-Elimination Methods-Interval halving method; Fibonacci search method, golden section search method, Point-Estimation Method: Successive quadratic estimation method, Gradient-based Methods: Newton-Raphson method, Bisection method, Secant method, Cubic search method

Multivariable Optimization: Optimality Criteria, Unidirectional Search, Direct Search Methods: Simplex, Hooke-Jeeves pattern search and Powell's conjugate direction method, Gradient-based Methods: Cauchy's (steepest descent) method, Newton's method, conjugate gradient method, variable – metric method.

Constrained Optimization: Kuhn-Tucker Conditions, Transformation Methods: Penalty function method, Sensitivity Analysis, Direct Search for Constrained Minimization: Variable elimination, Complex search and Random search methods, Linearized Search Techniques: Frank-Wolfe method, cutting plane method, Feasible Direction Method, Generalized Reduced Gradient Method, Gradient Projection Method.

Programming: Integer Programming, Geometric Programming

Books:

1. Sastry S.S., "Introductory methods of Numerical Analysis", Prentice Hall India, 2009.
2. Rao S.S., "Engineering Optimization: Theory and Practices", John Wiley and Sons, 4th Edition, 2009.
3. Kambo N.S., "Mathematical Programming Techniques" East West Press, 2009.
4. Deb Kalyanmoy, "Optimization for Engineering Design: Algorithms and Examples", Prentice Hall of India New Delhi, 2005.

Paper Title: Design of Experiments

Paper Code: ME9207

L	T	P
4	0	0

Introduction: Strategy of experimentation, some typical applications of experimental design, Basic principles, Guidelines for designing experiments, A brief history of statistical design, Using statistical design in experimentation.

Simple Comparative Experiments: Introduction, Basic statistical concepts, Sampling and sampling Distribution, Inferences about the Differences in means, randomized designs, Paired comparison Designs, Inferences about the Variances of Normal Distributions.

Introduction To Factorial Design: Basic definition and principles, Advantages of factorials, The two factor factorial design, General factorial design, Fitting response curves and Surfaces, Blocking in a factorial design.

Fitting Regression Models: Introduction, Linear regression models, Estimate of 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.

Taguchi Method Of Design Of Experiments: Concept design, Parameter design, Tolerance design, Quality loss function, Signal-to- Noise ratio, Orthogonal array experiments, Analysis of Mean (ANOM), Quality characteristics, Selection and testing of noise factors, Selection of control factors, Parameter optimization experiment, Parameter design case study

Analysis of Variance (Anova): Introduction, Example of ANOVA process, Degrees of freedom, Error variance and pooling, Error variance and application, Error variance and utilizing empty columns, the F-test.

Books:

1. Douglas C Montgomery, “Design and Analysis of Experiments”, John Wiley Publishers.
2. John P.W.M., “Statistical Design and Analysis of Experiments”, John Wiley Publishers.
3. Montgomery D.C., Runger G.C., “Introduction to Linear Regression Analysis”, John Wiley Publishers.
4. Myres R.H. and Montgomery D.C., “Response Surface Methodology Process and Product Optimization Using Designed experiments”, Wiley Publishers.
5. Taguchi, G, “Introduction to Quality Engineering”, UNIPUB, White Plains, New York.

Paper Title: Material Characterization

Paper Code: ME9208

L	T	P
4	0	0

Fundamentals of optics: Properties of light, Image formation, Magnification and resolution, Depth of field, focus and field of view, Optical microscope and its instrumental details, Variants in the optical microscopes and image formation

Microscopy: Opaque stop microscopy, Phase contrast microscopy, Dark field microscopy, Polarization microscopy, Differential interference contrast, Fluorescence microscopy, Sample preparation techniques for optical microscopy, Applications

Scanning Electron Microscopy (SEM): Introduction, Lens aberrations, Object resolution, Image quality, Imaging capabilities, Structural and elemental analysis, Instrumental details and image formation, various imaging techniques and spectroscopy, Sample preparation and Applications

X-ray Diffraction (XRD): Introduction, Bragg's Law, X-ray scattering, Factors affecting X-ray peaks, Instrumental details and analysis of XRD pattern, Residual stress measurements, Applications

Transmission electron microscopy (TEM): Introduction, Science of Imaging and diffraction, TEM instrumental details and variants in imaging techniques, Sample preparation procedures and instruments for various materials

Books:

1. Spencer, Michael, Fundamentals of Light Microscopy, Cambridge University Press, 1982.
2. David B. Williams, C. Barry Carter, " Transmission Electron Microscopy: A Textbook for Materials Science", Springer, 2009.
3. Joseph I Goldstein, Dale E Newbury, Patrick Echlin and David C Joy, "Scanning Electron Microscopy and X-Ray Microanalysis", 3rd Edition, 2005.
4. B.D. Cullity and S.R. Stock, "Elements of X-Ray Diffraction" Third edition, Prentice Hall, NJ, 2001.
5. Physical metallurgy and advanced materials' R.E. Small man and A.H.W. Ngan, Seventh edition, 2007, Elsevier Ltd., USA.

Paper Title: Additive Manufacturing

Paper Code: ME9209

L	T	P
4	0	0

Introduction to Additive Manufacturing: Process, Classification, Advantages, Additive v/s Conventional Manufacturing processes, Applications.

CAD for Additive Manufacturing: CAD software for 3D Modeling, CAD Data formats, Data translation, Data loss, STL format.

Additive Manufacturing Techniques: Stereo- Lithography, Laminated Object Manufacturing (LOM), Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Selective Laser Melting (SLM), Binder Jet technology; Process parameters, Process Selection for various applications.

Application Domains: Aerospace, Electronics, Healthcare, Defence, Automotive, Construction, Food Processing, Machine Tools.

Materials: Polymers, Metals, Non-Metals, Ceramics, Various forms of raw material- Liquid, Solid, Wire, Powder; Powder Preparation and their desired properties; Polymers and their properties; Support Materials.

Additive Manufacturing Equipment: Process Equipment- Design and process parameters, Governing Bonding Mechanism, Common faults and troubleshooting, Process Design.

Post Processing: Requirement and Techniques.

Product Quality: Inspection and testing, Defects and their causes.

Books:

1. Lan Gibson, David W. Rosen and Brent Stucker, “Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing”, Springer, 2010.
2. Andreas Gebhardt, “Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing”, Hanser Publisher, 2011.
3. Khanna Editorial, “3D Printing and Design”, Khanna Publishing House, Delhi.
4. CK Chua, Kah Fai Leong, “3D Printing and Rapid Prototyping- Principles and Applications”, World Scientific, 2017.
5. Zhiqiang Fan And Frank Liou, “Numerical Modelling of the Additive Manufacturing (AM) Processes of Titanium Alloy”, InTech, 2012.

Paper Title: Machine Learning

Paper Code: ME9210

L	T	P
4	0	0

Introduction: Overview of Machine learning**,** Relationship between AI and Machine Learning, Role of statistics in machine learning, Role of algorithms in machine learning, Introduction to Big Data

Coding in Python: Introduction to Python; Data types – numeric, Boolean, strings, lists etc.; Creating and using functions; Using conditional and loop statements; Storing data using sets, lists and tuples; Indexing data using dictionaries; Using Python libraries; File handling

Mathematics fundamentals: Linear Algebra, Probability Theory, Optimization, Statistical Decision Theory, Regression, Classification, Bias, Variance

Linear and Logistic Classification: Linear Regression, Multivariate Regression, Subset Selection, Shrinkage Methods, Principal Component Regression, Partial Least squares, Logistic Regression, LDA, Perceptron

Classical Techniques: Bayesian Regression, Binary Trees, Random Forests, SVM, Naïve Bayes, k-Means, kNN, GMM, Expectation Maximization, Applications

Neural Networks: Neural Networks - Introduction, Early Models, Perceptron Learning, Neural Networks – Back propagation, Initialization, Training & Validation, Parameter Estimation

Convolutional Neural Networks: CNN Operations, CNN architectures, Training, Transfer Learning, Applications

Books:

1. John Paul Mueller & Luca Massaron, “Machine Learning”, Wiley India Pvt. Ltd., 2018 (dummies edition).
2. Machine Learning by Tom Mitchell.
3. Introduction to Machine Learning by Ethem Alpaydin
4. Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, “Introduction to Statistical Learning”, Springer, 2013

Paper Title: Introduction to Numerical Methods **L T P**
Paper Code: ME9211 **4 0 0**

Getting Started: Algorithms; Convergence; Floating Point Number Systems and Arithmetic.

Root Finding: Bisection; Newton's Method; Secant Method; Accelerating Convergence; Roots of Polynomials.

Systems of Equations: Gaussian Elimination; Pivoting; Vector and Matrix Norms; Error Estimates and Condition Number; LU Decomposition; Direct Factorization; Special Matrices; Iterative Techniques; Conjugate Gradient Method; Nonlinear Systems of Equations.

Eigenvalues and Eigenvectors: Power and Inverse Power Method; Deflations; Tri diagonal Form.

Interpolation: Lagrange Form; Neville's Algorithm; Newton Form; Optimal Points for Interpolation; Piecewise Linear Interpolation; Hermite Interpolation; Regression.

Differentiation and Integration: Numerical Differentiation; Richardson Extrapolation; Numerical Integration - Newton Cotes; Gaussian Quadrature; Romberg Integration; Adaptive Quadrature; Improper Integrals and other Discontinuities.

Initial Value Problems of Ordinary Differential Equations: Theory and Key Concepts; Eulers's Method; Taylor Methods; Runge-Kutta Methods; Multistep Methods; Convergence and Stability Analysis; Error Control and Variable Step Size Algorithms; Systems of Equations and Higher-Order Equations; Absolute Stability and Stiff Equations.

Two-Point Boundary Value Problems: Finite Difference Method; Shooting Methods.

Elliptic Partial Differential Equations: Poisson Equation; Relaxation Methods; Multi-grid Method; Irregular Domains.

Parabolic Partial Differential Equations: Heat Equation; Stability; General Parabolic Equations; Polar Coordinates; Problems in Two Spatial Dimensions.

Hyperbolic Equations and the Convection-Diffusion Equation: Advection Equation; Convection-Diffusion Equation; the Wave Equation.

Textbooks:

1. Numerical Methods for Engineers by Steven C. Chapra, Raymond P. Canale. Publisher – McGraw Hill.
2. Numerical Methods by J. Faires, Richard Burden. Publisher - Brooks Cole.
3. Introduction to Applied Numerical Analysis by Richard W. Hamming, Publisher - Dover Books.
4. A Friendly Introduction to Numerical Analysis by Brian Bradie. Publisher - Pearson.

Paper Title: Mechanics of Solids	**L**	**T**	**P**
Paper Code: ME9212	**4**	**0**	**0**

Note: Topics to be chosen according to research requirements of the candidate.

Objectives and Applications of Solid Mechanics: Defining a problem in Solid Mechanics.

Governing Equations: Shape Changes in Solids; Internal Forces in Solids; Equations of Motion and Equilibrium for Deformable Solids; Principle of Virtual Work.

Constitutive Equations: General Requirements for Constitutive Equations; Material Behavior (Categories - Elastic/Plastic, Linear/Nonlinear, Deformation and Rotation Large/Small, Time and Rate Dependent/Independent); Soils; Single Metal Crystals; Contact and Interfaces.

Solutions to simple Boundary and Initial Value Problems: Axially and Spherically Symmetric Solutions to Quasi-Static - Linear Elastic, Elastic-Plastic, Large Strain Elasticity Problems; Dynamic Solutions to - Linear Elastic Materials.

Solutions for Linear Elastic Solids: General Principles; Plane Problems - Airy Function, Complex Variable; 3D Problems; Plane Anisotropic Problems; Dynamic Isotropic Problems; Energy Method; Reciprocal Theorem; Energetics of Dislocation; Ritz Method - Natural Frequency.

Solutions for Plastic Solids: Slip-Line Field Theory; Bounding Theorem.

Finite Element Analysis in Solid Mechanics: FEM Software Usage; FEM for - Static Linear Elasticity, Dynamic Linear Elasticity, Hypoelasticity, Hyperelasticity, Viscoplasticity; Advanced Element Formulation - Incompatible Modes, Reduced Integration, Hybrid Elements.

Modeling Material Failure: Fracture and Fatigue under Static and Cyclic Loading; Fracture and Fatigue Criteria - Stress and Strain Based; Failure by Crack Growth; Energy Methods in Fracture Mechanics; Plastic Fracture Mechanics; Linear Elastic Fracture Mechanics of Interfaces.

Solutions for Rods, Beams, Plates and Shells: Dyadic Notation; Rods; Thin Shells; Generalized Shells; Membranes; Flat Plates.

Textbooks:

1. Applied Mechanics of Solids by Allan F. Bower. CRC Press.
2. Continuum Mechanics of Solids by Lallit Anand, Sanjay Govindjee. Oxford University Press.
3. Continuum Mechanics: Elasticity, Plasticity, Viscoelasticity by Ellis H. Dill. CRC Press.

Paper Title: Advanced Mechanics of Materials **L T P**
Paper Code: MME103 **4 0 0**

SECTION-A

Stress, Strain, Stress-Strain Relations, and Introductory Elasticity
Stress, Stress Tensor, 2D and 3D Stress and Mohr Circle. Strain, Equations of Compatibility, Strain Measurement. Stress-Strain Relations, Hooke's Law, Poisson's Ratio. Strain Energy, Strain Energy for Common Structural Members, Components of Strain Energy, Saint-Venant's Principle. Plastic Deformation, Simple Tension True Stress-True Strain curve and Instability, Plastic Stress-Strain Relations, Plastic Stress-Strain Increment Relations. Plane Stress Problems, Plane Stress Problems, Airy Stress Function, Solution of Elasticity Problem, Thermal Stresses, Stress due to Concentrated Load, Stress Concentration, Contact Stress.

Failure Criteria
Failure by and Criteria for Yielding and Fracture, Failure Theories: Max. Shearing Stress, Max. Distortion Energy, Octahedral Shearing Stress, Max. Principal Stress, Mohr's, Coulomb-Mohr; Fracture Mechanics, Failure Criteria for Metal Fatigue, Fatigue Life, Impact Load, Dynamic and Thermal Effects.

Torsion of Prismatic Bars
Elementary Theory, General Solution of Torsion Problem, Prandtl's Stress Function and Membrane Analogy, Torsion of Thin-walled Members: Open Cross-section, Multiply Connected, Restrained; Fluid Analogy and Stress Concentration, Curved Circular Bars, Helical Springs. Elastic-Plastic Torsion.

Beams, Plates, and Shells
Beams: Exact and Approximate Solutions, Curved Beams. Beams on Elastic Foundations: Infinite, Semi-infinite, Finite Beams, Beams Supported by equally Spaced Elastic Elements, Finite Difference Solutions. Thin Plates: Basic Assumptions and Relations, Boundary Conditions, Simply Supported Rectangular Plates, Axi-symmetrically Loaded Circular Plates, Deflection by Energy Method, Finite Element Solution. Thin Shells: Basic Assumptions, Membrane Action, Shells of Revolution, Cylindrical Shells of General Shape.

(12 hours)

SECTION-B

Numerical Methods
Finite Differences and Equations, Curved Boundaries, Boundary Conditions, Finite Element Method, Properties of a Finite Element, Formulation of the Finite Element Method, Triangular Element, Use of Digital Computers.

Axisymmetrically Loaded Members
Thick-walled Cylinders, Max. Tangential Stress, Failure Theories, Compound Cylinders, Perfectly Plastic Thick-Walled Cylinders. Rotating Disks: Constant and Variable Thickness, Uniform Stress; Elastic-Plastic Stresses in Rotating Disks, Thermal Stresses in Thin Disks and Long Cylinders, Finite Element Solution.

Energy Methods
Work done in Deformation,Theorems: Reciprocity, Castigliano, Crotti-Engesser; Statically Indeterminate Systems, Principles: Virtual work, Minimum Potential Energy; Rayleigh-Ritz Method.

Elastic Stability
Critical Load, Buckling of Column, End Conditions, Critical and Allowable Stress, Initially Curved, Eccentrically Loaded and Secant Formula, Energy Methods, Finite Differences Solution.

(12 hours)

TEXT BOOKS			
S. No.	**NAME**	**AUTHOR(S)**	**PUBLISHER**
1	Advanced Strength and Applied Elasticity	Ugural and Fenster	Prentice Hall, 2003
2	Advanced Mechanics of Material	Boresi and Schmidt	Wiley, 1993
3	Advanced Strength and Applied Stress Analysis	Budynas	McGraw Hill, 1999

Paper Title: Continuum Mechanics **L T P**
Paper Code: MME201 **4 0 0**

SECTION-A

Introduction - What is Continuum Mechanics?

Tensors – Indicial notation, Tensor Algebra, Tensor Calculus, Curvilinear Coordinates

Kinematics of a Continuum - Description of motions of a continuum, Kinematic equation for rigid body motion, Infinitesimal deformation, Infinitesimal rotation tensor, rate of deformation and spin tensor, Conservation of mass, Compatibility conditions for infinitesimal strain and rate of deformation components, Deformation gradient, local rigid body motion, Finite deformation, Polar decomposition theorem, Stretch and Rotation tensors, Right Cauchy-Green, Lagrangian strain tensor, Left Cauchy-Green, Eulerian strain tensor, Change of area and volume due to deformation, Components of deformation tensors in other coordinates, Current configuration as the reference configuration

Stress – Stress Tensor, Symmetry-Principle Of Moment Of Momentum, Equations Of Motion-Principle Of Linear Momentum, Boundary Condition , Piola Kirchhoff Stress Tensors, Equations Of Motion w.r.t. Reference Configuration, Stress Power, Heat Flow, Energy Equation, Entropy Inequality, Integral Formulations of the General Principles of Mechanics.

SECTION-B

Elastic Solid – Isotropic Linear Elastic Solid, Anisotropic Linear Elastic Solid, Isotropic Solid under Large Deformation.

Newtonian Viscous Fluid – Fluids, Compressible and Incompressible Fluids, Newtonian Fluids, Interpretation of λ and μ, Incompressible Newtonian Fluid, Navier-Stokes Equations for Incompressible Fluids, Boundary Conditions, Streamline, Pathline, Steady, Unsteady, Laminar, and Turbulent Flow. Plane Couette Flow, Plane Poiseuille Flow, Hagen-Poiseuille Flow, Dissipation Functions for Newtonian Fluids, Energy Equation For A Newtonian Fluid, Vorticity Vector, Irrotational Flow, Concept Of A Boundary Layer, Compressible Newtonian Fluid, Energy Equation In Terms Of Enthalpy, Acoustic Wave.

Reynolds Transport Theorem and Applications – Green's Theorem, Divergence Theorem, Integrals Over A Control Volume And Integrals Over A Material Volume, The Reynolds Transport Theorem, The Principle Of Conservation Of Mass, The Principle Of Linear Momentum, Moving Frames, A Control Volume Fixed With Respect To A Moving Frame,The Principle Of Moment Of Momentum, The Principle Of Conservation Of Energy, The Entropy Inequality: The Second Law Of Thermodynamics.

Non-Newtonian Fluids – Linear Maxwell Fluid, Relaxation Spectra; Nonlinear Viscoelastic Fluid, Relative Deformation Tensor; Viscometric Flow, Channel Flow, Couette Flow.

TEXT BOOKS			
S. No.	**NAME**	**AUTHOR(S)**	**PUBLISHER**
1	Continuum Mechanics	Lai, Rubin, and Krempl.	Elsevier, 2010

RECOMMENDED BOOKS			
1	Continuum Mechanics	Malvern	Pearson, 1966
2.	Mechanics and Thermodynamics of Continua	Gurtin, Fried, Anand	Cambridge, 2010
3.	Continuum Mechanics for Engineers	Mase and Mase	CRC, 1999
4.	Continuum Mechanics – A concise Theory	Chadwick	Dover, 1976
5.	Fundamentals of Continuum Mechanics	Bechtel	Springer, 2014

Paper Title: Advanced Manufacturing Processes **L T P**
Paper Code: MME202 **4 0 0**

SECTION-A

Introduction:
Classification, Advantages & limitations of non-conventional machining, Hybrid Machining, Ultrasonic machining (USM)-Principle of operation, process details, applications and advantages, limitations of USM.

Abrasive and Water Jet Machining:
Basic principle, mechanism of material removal, working principle of Abrasive jet machining (AJM), water jet machining (WJM), merits & demerits, application.

Chemical Machining (CM):
Working principle, process characteristics, procedures, advantages & disadvantages of chemical machining.

SECTION-B

Thermal Metal Removal Processes:
Working principles, Mechanism of material removal, process parameters, advantages & limitations, applications of processes like electric discharge machining(EDM), Electron Beam Machining (EBM), Ion beam machining (IBM), Plasma arc machining (PAM), Laser beam machining(LBM).

Electrochemical Processes:
Fundamentals, details of machining setup, materials and selection of tools, applications, Concept of others processes like ECG, Electrochemical deburring etc.

TEXT BOOKS			
S. No.	**NAME**	**AUTHOR(S)**	**PUBLISHER**
1	Advanced Machining Processes,	V K Jain	Allied
2.	Unconventional machining Methods	Benedict	McGraw-Hill
3	Production Technology	HMT	TMH
4	Non Convectional Machining	M. Adithan	John Wiley
5.	Non-Conventional Machining	P.K. Mishra	Narosa Publishers
6.	Modern machining process	Shan &Pandey	TMH

Paper Title: Advances in Engineering Materials **L T P**
Paper Code: MME203 **4 0 0**

SECTION-A

Selection of materials: Service requirement, Structure-Property correlations and reappraisal of the role of crystal structure and structural defects on properties.

Material Characterization: Stereographic Projections, X-ray diffraction, crystal structure and phase identification, residual stress measurement and other applications.

Thermal Analysis Techniques: Outline of thermal analysis, technique, description of DTA/DSC/TGA techniques and instrumentation, applications, and case studies

Optical microscopy: light optics, microscope components, possibilities, and limitations.

Scanning Electron Microscopy: Optics and performance of a SEM, Image interpretation, crystallographic information in a SEM, analytical microscopy

Scanning Tunneling Microscopy: Construction and operation, Image interpretation

Transmission Electron Microscopy: Construction and operation of a TEM, Electron Diffraction and image interpretation.

SECTION-B

Synthetic materials: Classifications and structure of polymers, class transition temperature, mechanical properties of polymers. Artificial and synthetic materials.
Nano materials: Classification, the structure, methods of their production, their properties and their sphere of applications.

Smart materials: Shape Memory Alloys, Varistors and Intelligent materials for bio-medical uses including poly-acrylates, ABS plastics, poly-methacrylate, nylon and teflon. Applications and development of these materials.

TEXT BOOKS			
S. No.	**NAME**	**AUTHOR(S)**	**PUBLISHER**
1	Callister's Materials Science and Engineering	William D. Callister	John Wiley India Pvt. Ltd., 2010
2.	Engineering Material Technology	James A. Jacobs & Thomas F. Kilduff.	Prentice Hall, 2005.
3	Foundations of Materials Science and Engineering	William F. Smith.	McGraw Hill.
4	Materials characterization techniques	Sam Zhang; L Li; Ashok Kumar	CRC Press, 2009

Paper Title: Structural Dynamics **L T P**
Paper Code: MME204 **4 0 0**

SECTION-A

Basic concepts:
Introduction to structural dynamics; Modeling of structural components and systems; FE route of structural dynamics and its limitations; Experimental route of structural dynamics and its limitations; Understanding structural dynamics in time domain versus frequency domain. Spring-mass model; Free vibrations of SDOF, 2-DOF and MDOF system; Dynamic matrix equation; Eigenvalues; Eigenvectors; Modeshapes; Orthogonality of normal modes; Damping ratios; Drive point and cross frequency response functions; Receptance, Mobility, Accelerance, Real modes, Complex modes.

SDOF system:
Degrees of freedom; Undamped system; Springs in parallel or in series; Newton's law of motion; Free body diagram; D' Alembert's principle; Solution of differential equation of motion; Frequency and period; Amplitude and motion.Proportional versus non-proportional damping; Equation of motion; Analysis of critically damped system; Analysis of under-damped system; Analysis of over-damped system. Harmonic excitation for undamped and damped systems; Evaluation of damping at resonance; Bandwidth method to evaluate damping; Energy dissipated by viscous damping; Equivalent viscous damping; Response to support motion; Force transmitted to foundation; Seismic instruments; Response of SDOF system to harmonic loading. Nonlinear SDOF model; Integration of the nonlinear equation of motion; Constant acceleration method; Linear acceleration step-by-step method; The Newmark beta method.

SECTION-B

Introduction to finite element method:
Types of finite elements; Types of loading; Element division; Element connectivity; Linear shape functions; Isoparametric formulation of shape functions; Types of shape functions; Development of elemental stiffness matrix; Assembly of global stiffness matrix; Development of elemental body force vector; Development of elemental traction force vector; Assembly of global load vector; Development of elemental mass matrix; Assembly of global mass matrix.

Structural dynamic analysis of beams using MATLAB:
Flexural vibrations of uniform beams; Solution of equation of motion in free vibration; Natural frequencies and mode-shapes for uniform beams with both ends simply supported, both ends free, both ends fixed, one end fixed and other end free, one end fixed and other end simply supported; Orthogonality condition between normal modes.

TEXT BOOKS			
S. No.	**NAME**	**AUTHOR(S)**	**PUBLISHER**
1	Structural Dynamics Theory and Computation	Mario Paz and William Leigh	Kluwer Academic Publisher, 2004
2.	Fundamentals of Structural Dynamics	R. Craig and Andrew Kurdila	John Wiley and Sons, 2006

3	Dynamics of Structures	J. L. Humar	Balkema Publishers, Edition 2002
4	Structural Dynamics for Engineers	Hans Anton Buchholdt	Thomas Telford Publishers, 1997

Paper Title: Advanced Machine Design **L T P**
Paper Code: MME301 **4 0 0**

SECTION-A

Introduction:
Importance of machine design in industry; Basic concepts of machine design including types of loading, stress, strain, strength, factor of safety, types of failures, computer-aided-design, stress concentration, statistical nature of mechanical properties of materials, fits, tolerances and surface finish.

Fatigue failure based design:
Stress-life approach; strain-life approach; LEFM approach, Estimated S-N diagrams; Notch sensitivity; Residual stresses; Designing for high cycle fatigue; Designing for fully reversed uni-axial stresses; designing for fluctuating uniaxial stresses, Designing for multi-axial stresses in fatigue.

Surface failure based design:
Surface geometry; mating surfaces; Effect of roughness, velocity, rolling and lubricant on friction; Adhesive wear coefficient; Abrasive wear; Corrosion wear; Surface fatigue; Spherical contact; Cylindrical contact; General contact; Dynamic contact stress, Surface fatigue failure models of dynamic contact.

Impact based design:
Energy methods, longitudinal stress waves in elastic media impact on beams, torsional impact on shafts and longitudinal impacts on helical springs

SECTION-B

Vibration based design:
Methods of dynamic design of machines; Structural dynamic modifications; Application of vibration based design to an industrial case study such as a drilling machine.

Thermal based design:
Effect of short term and long term properties of materials on design; creep and stress relaxation; Elementary analysis of thermal stresses; thermal fatigue based design.

Reliability based design:
Guarantee versus warranty; Accelerated life testing (ALT); Design of ALT plans; Exponential Model and its application; Weibull model and its applications.

Optimum design:
Design vector; Design constraints; Constraint surface; Objective function surfaces; Multi-objective optimization using response surface method and its application in machine design.

TEXT BOOKS			
S. No.	**NAME**	**AUTHOR(S)**	**PUBLISHER**

1	Mechanical Engineering Design	Joseph Edward Shigley& Charles R. Mischke	Mc. Graw Hill (2007)
2.	Machine Design, An Integrated Approach	Robert L. Norton	Pearson Education (2007)
3	Design of Machine Members	Vallance and Doughtie	McGraw Hill, New York, 2005