Savitribai Phule Pune University, Pune

Maharashtra, India

Faculty of Science and Technology

Rules & Regulations, Structure and Syllabus

Ph. D. Course Work (Engineering)

(With effect from Academic Year 2025-26)

https://unipune.ac.in/

Contents

Ph. D. Course Work

Preface by Dean - Faculty of Science and Technology

Dear Ph. D. Scholars,

It is with great pleasure to introduce the new Ph. D. Course Work syllabus for the Faculty of Science and Technology at Savitribai Phule Pune University. This comprehensive booklet has been meticulously developed to provide our doctoral students with a robust academic framework that is both challenging and supportive. The pursuit of a Doctor of Philosophy (PhD) represents the pinnacle of academic dedication and the transition from a consumer of knowledge to a creator of it. As the Faculty of Science and Technology, we recognize that the challenges of the 21st century—ranging from climate resilience and sustainable energy to the ethical integration of artificial intelligence—require researchers who are not only technically proficient but also philosophically grounded and methodologically rigorous. The journey of a Ph. D. is one of intellectual discovery and significant contribution to one's field. We've focused on creating a flexible yet structured program that allows you to tailor your studies to your specific research interests while ensuring you meet the highest academic standards.

This syllabus for the PhD Course Work has been meticulously designed to serve as the foundational bridge between advanced postgraduate study and independent, high-impact research. The course work motivates students by linking their research journey with career growth and future opportunities. It helps in shaping mindset, developing skills, and creating a sense of direction. Students often come from diverse backgrounds. Coursework helps them reach a common baseline of knowledge.

A Ph. D. is more than just a degree; it's a testament to your passion, perseverance, and dedication. This booklet is your roadmap, guiding you through the initial stages of your doctoral research. I encourage you to make the most of the resources available to you, engage actively with your professors and peers, and approach your studies with a spirit of inquiry and innovation.

Dr. Pramod Patil
Dean (Science and Technology)
Savitribai Phule Pune University.

Ph. D. Course Work (Engineering)

Rules ,Regulations and Guidelines

As per rule regulations of SPPU Circular 07/2025 Ref number: PGS/87 dated 09/01/2025 and University Grants Commission (Minimum Standards and Procedures for Award of Ph. D. Degree) Regulations, 2022.

General Guidelines

1. The coursework is for 16 credits.
2. The recognized research center, based on the recommendations of the Research Advisory Committee, shall prescribe courses for the Ph. D. scholar, including research methodology and two subject-specific advanced courses, to be completed within two years of registration.
3. A course on Publication Ethics must be completed within two years from the date of registration by the Ph. D. scholar.
4. Candidates with an M.Phil. degree from SPPU who are admitted to the Ph. D. program, or those who have completed M.Phil. coursework and are permitted to proceed to a Ph. D., will be exempted from Ph. D. coursework, provided both programs are in the same subject. If the M.Phil. and Ph. D. programs are in different subjects, the candidate must complete Courses 2, 3, and 5 as specified, as per University Circular No. 07/2025 Reference Number PGS/87 dated 9th January 2025.
5. All other candidates admitted to the Ph. D. program are required to complete the coursework approved by the Academic Council of SPPU, achieving a minimum of 55% marks or its equivalent grade on the UGC 10-point scale, within the first two years of registration. Candidates will be permitted to continue with their Ph. D. studies and submit the thesis only after fulfilling these requirements.
6. Grades in the course work, including research methodology courses, shall be finalized after a combined assessment by the Research Advisory Committee and the Place of Research, and the final grades shall be communicated to the P. G. Admission Section of the SPPU.
7. All Ph. D. scholars, irrespective of discipline, shall be required to undergo training in teaching /education /pedagogy/writing related to their chosen Ph. D. subject during their doctoral period. Ph. D. scholars may also be assigned 4-6 hours per week of teaching/research assistantship for conducting tutorial or laboratory work and evaluations.
8. The Research Advisory Committee can also recommend online/offline courses offered by UGC/ National Agency/ MOOCs/ SWAYAM/ NPTEL., etc., of 4 Credits each as part of the credit requirements for the Ph. D. program.
9. If necessary, course work courses 1, 3 and 6 as specified may be carried out by candidates in sister Departments / Institutes either within or outside the University for which due credit will

be given to them. The candidate can opt for such courses upon recommendation of the Research Advisory Committee of the Research Center.

10. University Department/ Research Centre may introduce additional course(s) in respect of course 3 on recommendations of the Research Center. The syllabus of such course(s) will be prepared by the concerned teacher and will be flexible to accommodate new developments in that area.

11. The policies and procedures determined by the University will be followed for the conduct of examinations and declaration of the result of the candidate.

12. Responsibility of the Course work components

    (a) Research Methodology - Research Center & research Supervisor

    (b) Seminar/ Conference/Workshop (National/ International) and Presenting paper/poster - Research Center & research Supervisor

    (c) Two Subject specific advanced level courses - Research Center

    (d) Research and Publication ethics - Research Center shall conduct the UGC approved 02 credits course as per UGC letter No. D.O.F. 1-1/2018 (Journal/CARE) Dated Dec.2019 and SPPU circular No. 65/2020 dated 3rd march 2020 **OR** Research Scholar can complete the Research and Publication ethics course run by the Centre of Publication Ethics SPPU.

    (e) Pedagogical Training/ Industrial Visit Report / Assessment Statement - Research Center & research Supervisor

13. The continuous assessment of theory course shall be evaluated on the basis of the class tests/assignment studies/quizzes. There shall be minimum two class tests/ assignments / case studies/ quizzes for each theory course. The marks obtained shall be displayed on the notice board within 10 days of conducting it.

14. The End Semester Examination for the theory course shall be of 50 marks and TWO hours duration.

15. The concerned and appropriate faculty of the Research Centre. will be responsible for paper setting, preparing the schedule of the examination, conducting the examination, assessment, awarding the grades for the ESE of the Courses.

16. Research scholars may select advanced topics aligned with their specific research domain, even if such topics are not explicitly included in the prescribed syllabus, provided that the total learning engagement per course is approximately 120 hours. Such topics should be duly approved by concern Board of Studies.

Award of Credits for Ph. D. Course Work

Table -1: Percentage to grade and grade point

Sr. No.	Grade Letters	Grade Points	Marks
1	O (Outstanding)	10	90 to100
2	A+ (Excellent)	9	80 to 89
3	A (Very Good)	8	75 to 79
4	B+ (Good)	7	70 to 74
5	B (Above average)	6	65 to 69
6	C (Average)	5	60 to 64
7	D (Pass)	4	55 to 59
8	F (Fail)	0	<55
9	Ab (Absent)	0	-

Structure of Ph. D. Course Work (Engineering)

Sr.	Course Code	Name of the Course	Credits	No of Hours	Marks
1	RM101	Research Methodology	4	60	100
2	SCW102	Attending Seminar/ Conference/Workshop (National/ International)	1	-	-
3	-SPC1	Subject specific advanced level courses 1	4	60	100
4	-SPC2	Subject specific advanced level courses 2	4	60	100
5	RPE103	Research and Publication Ethics	2	30	50
6	PIA104	Pedagogical Training/ Industrial Visit Report / Assessment Statement	1	30	25
Total			16	240	375

***Two Subject specific advanced level courses**

Course Code	Name of the Course
CVl-SPC1	Mathematics for Civil Engineering
CVl-SPC2	Advances in Civil Engineering
MEC-SPC1	Mathematics for Mechanical Engineering
MEC-SPC2	Advances in Mechanical Engineering
ETC-SPC1	Mathematics for Electronics and Telecommunication Engineering
ETC-SPC2	Advances in Electronics and Telecommunication Engineering
ELE-SPC1	Mathematics for Electrical Engineering
ELE-SPC2	Advances in Electrical Engineering
CHE-SPC1	Mathematics for Chemical Engineering
CHE-SPC2	Advances in Chemical Engineering
COM-SPC1	Mathematics for Computer Engineering
COM-SPC2	Advances in Computer Engineering
IN-SPC1	Mathematics for Instrumentation Engineering
IN-SPC2	Advances in Instrumentation Engineering
PEE-SPC1	Mathematics for Production and Industrial Engineering
PEE-SPC2	Advances in Production and Industrial Engineering
PPT-SPC1	Mathematics for Production and Industrial Engineering
PPT-SPC2	Advances in Production and Industrial Engineering

Savitribai Phule Pune University Ph. D. Course Work (Engineering)		
RM-101 - Research Methodology		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Prerequisite Courses :

1. Differentiation, Integration, Maxima and Minima, Matrices and Determinants
2. Knowledge of basic statistics (mean, median, variance, standard deviation, probability concepts)

Course Objectives: The course aims to:
To familiarize the scholars with concepts and techniques in Calculus, Fourier series and Linear Algebra. The aim is to equip them with the techniques to understand advanced level mathematics and its applications that would enhance analytical thinking power, useful in their disciplines.

Course Outcomes: Upon successful completion of this course, students will be able to:

- **CO1:** Understand the fundamental concepts and types of research, including qualitative and quantitative approaches.
- **CO2:** Select suitable tools for data collection and analysis.
- **CO3:** Design appropriate research methodology
- **CO4:** Analyze and interpret data using appropriate statistical tools and software.
- **CO5:** Apply appropriate hypothesis testing techniques to analyze research data and draw statistically valid conclusions.

Course Contents

Module I - Introduction to Research and Literature Review

Meaning of Research, Objectives of Research, and Motivation in Research, Types of Research, qualitative and quantitative approaches for research, Research Approaches, Significance of Research, and Research Process, Criteria of Good Research, Overview of literature Survey, Research Problem Meaning of research problem, Sources of research problem Criteria / Characteristics of a good research problem Errors in selecting a research problem Scope and objectives of research problem

Case Study : Code of Ethics, IEEE Code of Ethics, ACM Software Engineering Code of Ethics and Professional Practice, Code of Ethics especially covering Engineering discipline, various aspects- environment, sustainable outcomes, employer, general public, and Nation, Engineering Disasters.

Module II - Methods of data collection

Methods of Data Collection, Collection of Primary Data, Observation Method, Interview Method, Collection of Data through Questionnaires, Collection of Data through Schedules, Difference between

Questionnaires and Schedules, Some Other Methods of Data Collection, Collection of Secondary Data, Selection of Appropriate Method for Data Collection, Case Study Method, Sampling

Case Study : Engineering dictionary, Shodhganga, The Library of Congress, Research gate, Google Scholar, Bibliometrics, Citations, Impact Factor, h-index, I-index, plagiarism, copyright infringement

Module III - Research Design

Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs

Module IV - Processing and Analysis of Data

Processing Operations, Some Problems in Processing, Elements/Types of Analysis, Statistics in Research, Measures of Central Tendency, Measures of Dispersion, Measures of Asymmetry (Skewness), Measures of Relationship, Simple Regression Analysis.

Module V - Testing of Hypothesis

Basic Concepts Concerning Testing of Hypotheses, Tests of Hypotheses, Hypothesis Testing of Means, Hypothesis Testing of Proportions, Hypothesis Testing for Differences between Means, Hypothesis Testing for Difference between Proportions, Chi-square as a Test for Comparing Variance, Steps Involved in Applying Chi-square Test

Learning Resources

Text Books

1. Donald Cooper and PS Schindler (2009), Business Research Methods, 9th edition, Tata McGraw Hill.
2. C.R.Kothari (2004), Research Methodology-Methods and Techniques, New Age International Publishers

Reference Books:

1. Uma Sekaran (2010), Research Methods for Business, 4th edition, Wiley.
2. Ranjit Kumar (2009), Research Methodology, 2nd edition, Pearson Education
3. Naresh Malhotra and S Dash (2009), Marketing Research, 5th edition, Pearson Prentice Hall

SWAYAM / MOOC / YouTube Links

1. https://www.youtube.com/playlist?list=PLm-zueI9b64QGMcfn5Ckv_8W5Z1d3vMBY
2. https://onlinecourses.swayam2.ac.in/cec20_hs17/preview
3. https://onlinecourses.nptel.ac.in/noc23_ge36/preview

Savitribai Phule Pune University **Ph. D. Course Work (Engineering)**		
SCW102- Attending Seminar/ Conference/ Workshop (National/ International)		
Teaching Scheme	**Credits**	**Examination Scheme**
-	01	-

Nature of the Course:

Students admitted for Ph. D. program in Engineering have to attend/ participate in the Seminars/ Workshop/ Conference at National/ International level organized by various educational institutes or research organizations. The certificate of Participation/Attendance will have to be submitted for One Credit.

Course Objectives:

Ph. D. scholars should deliver the technical seminar on the research work related topic and present their outcome of research in seminar / conference at national or international level. Participation in academic seminars, conferences, and workshops enhances research exposure, fosters collaboration, and strengthens presentation skills. These guidelines ensure systematic preparation, ethical conduct, and effective representation.

Seminar Guidelines

1. Seminar in the form of paper should be based on thrust areas in specific research domain.
2. Research scholar should do literature survey, identify the topic for seminar and finalize the same in consultation with Guide/Supervisor.
3. Report or paper should be compiled in the standard format as per guidelines of conference or workshop and present in conference.
4. Seminar should be assessed jointly by the pair of Internal and External Examiners
5. Following points must be assessed during the presentation of Credit Seminar
   i. Quality of Literature survey and Novelty in the topic
   ii. Relevance to the specialization or research domain
   iii. Understanding of the topic
   iv. Quality of Written and Oral Presentation

Guidelines for Conference/Workshop Selection

- The seminar/conference/workshop must be directly related to the candidate's research area or field of study.
- Preference is given to reputed and indexed conferences (Scopus, Web of Science, IEEE, Springer, Elsevier, etc.).

Guidelines for Presenting Papers or Posters

- **Abstract Submission**: Carefully follow the submission guidelines for the conference. Your abstract should be a concise summary of your research, including the problem, methods, key findings, and conclusion.
- **Authors** : Student should be first author and his/her guide should be second author. (No third author is allowed, unless he/she is co-guide).
- **Affiliation:** Affiliation must be like. $firstname$ $last name $, Research Scholar, Department of XXX Engineering, $Name of Research Center$ Affiliation to Savitribai Phule Pune University (SPPU) Pune. **(Reference : Circular No 124/2025 dated 02/05/2025)**
- **Paper Preparation:** If presenting a paper, adhere to the specified word count and formatting guidelines. Your presentation should be a distillation of the key points of your paper, not a reading of the entire text. Practice your talk to ensure it fits within the allotted time.
- **Poster Design**: For a poster presentation, your poster should be visually appealing and easy to read from a distance. Use clear headings, charts, and images to convey your message. The content should be a summary of your research, including an introduction, methodology, results, and conclusions.
- **Presentation and Q&A:** Be prepared to stand by your poster during the designated session to discuss your research with attendees. For paper presentations, be ready to answer questions from the audience. Listen carefully to each question and provide a clear, concise answer. If you don't know the answer, it's okay to say so and offer to discuss it further later.
- **Funding:** Check with your department or faculty for available travel grants or funds to support your attendance. It's often necessary to apply for these well in advance.
- **Departmental Approval:** Always inform your supervisor and departmental head about your intention to attend and present. They may need to approve your absence and provide a letter of recommendation for any funding applications.
- **Ethical & Academic Integrity** : Avoid duplicate submissions or self-plagiarism. Cite sources appropriately in presentations and posters. Represent institutional work accurately without fabrication or exaggeration.

Savitribai Phule Pune University **Ph. D. Course Work (Engineering)**		
CVl-SPC1 - Mathematics for Civil Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Course Objectives:

1. Develop advanced mathematical proficiency in matrix algebra and linear transformations to facilitate the application of finite element methods in structural and geotechnical analysis.
2. Master numerical techniques for solving linear systems and ordinary differential equations to model dynamic engineering problems where analytical solutions are unavailable.
3. Formulate and solve linear and partial differential equations, including parabolic and hyperbolic systems, to address stability analysis and optimization in civil engineering designs.
4. Apply statistical measures and probability distributions to evaluate data reliability, perform hypothesis testing, and assess the structural integrity of engineering systems.
5. Utilize vector calculus and integral theorems to interpret physical phenomena such as fluid motion, streamlines, and the fundamental equations of motion.

Course Outcome:

1. CO1: Scholars will be able to apply Eigen value and Eigen vector analysis to solve complex linear systems and perform high-level finite element transformations.
2. CO2: Scholars will demonstrate the ability to implement Runge-Kutta and Predictor-corrector methods to simulate real-world engineering challenges through numerical approximation.
3. CO3: Scholars will be proficient in using 1-D and 2-D solution methods for PDEs to optimize engineering processes and ensure structural stability.
4. CO4: Scholars will be capable of performing correlation, regression, and t-tests to validate experimental research data and quantify reliability estimates.
5. CO5: Scholars will successfully apply Green's, Gauss's, and Stoke's theorems to derive continuity equations and solve Bernoulli's equations in fluid and solid mechanics.

Course Contents

Module I - Matrices

Definitions of various types of matrices, Eigen value and Eigen vectors, Applications of matrices for finite element methods, Rank of matrix, system of linear equation, Linear Dependent and Indecent, Linear and Orthogonal Transformation.

Module II - Numerical Methods

Numerical solution of system of linear equations: Gauss elimination method, Numerical Method for finding Eigen value and Eigen vector.

Numerical solutions of ordinary differential equation: Euler's method, Modified Euler's method, Runge–kutta method, Taylor's series method, Predictor-corrector method, Applications to Engineering problems.

Module III - Differential Equations and application

Linear Differential Equation: n ^ th order with constant coefficients, complementary function, Particular Integral, General Method, Method of variation of parameter.

Partial Differential Equation: Parabolic and Hyperbolic system, 1-d and 2-d solution method, stability analysis, PDE application in optimization

Module IV - Statistics and Probability

Measures of Central Tendency, Standard Deviation, Coefficient of variations, Moment, Skewness and kurtosis, correlation and Regression, Reliability of regression estimates. Probability, Probability density function, Probability distributions: Binomial, Poisson, Normal, Test of hypothesis, Chi-square test, t-test.

Module V : Vector Differential and Integral Calculus

Physical interpretation of vector differentiation, Vector differential operator, Gradient, Divergence and curl, Directional Derivative, Solenoidal, Irrotational, Scalar Potential. Integral: Line, work-done, Green's Lemma, Gauss's Divergence theorem, Stoke's theorem, Continuity Equation, Streamline, Equations of motion, Bernoulli's Equation.

Learning Resources

Reference Books:

1. Kreyszig, Erwin. Advanced Engineering Mathematics.
2. Rao, Singiresu S. Applied Numerical Methods for Engineers and Scientists.
3. Reddy, J.N. An Introduction to the Finite Element Method.
4. Trivedi, K. S. Probability and Statistics with Reliability, Queuing, and Computer Science Applications.
5. Boyd, Stephen, and Vandenberghe, Lieven. Convex Optimization. (For Unit III - Optimization Focus)

Savitribai Phule Pune University **Ph. D. Course Work (Engineering)**		
CVl- SPC2 - Advances in Civil Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Any THREE of the following topics or modules can be covered from any section as part of the course.

Course Objectives: The course aims to:

- To familiarize the students with latest concepts and techniques in Civil Engineering. The latest concepts will help the students to know what are the latest trends in civil engineering which will help them in identifying the topic of research and further completion of their research work.

Course Contents - STRUCTURAL ENGINEERING

Module I - Advanced Solid and Structural Mechanics

Three dimensional elasticity problems, Torsion of open section, Thermal Stresses, Fracture mechanics. Kirchoff and Mindlin theory of plates, higher order shear deformation theories, classical theories of skew plates, Shell surfaces, bending theory of shells

Module II - Advanced Composite Materials and Structural Dynamics

Mechanics of modern materials, laminated composites, functionally graded materials. Application to plate and shell structures.Structural dynamics, Forced and Damped vibration, modal analysis, response spectra, seismic design of multistoried buildings, codal provisions.

Module III - Advanced FEM for Elasticity and Nonlinear Structural Elements

Finite Element Method, 2D and 3D applications in plane and three dimensional elasticity problems. Analysis of plate and shell structures. Applications using proper software.Nonlinear analysis of structural elements. Material and geometric nonlinearity. Applications for beam, plates and shells.

Module IV - Optimization and Stability of Structural Elements

Multi- variable and Multi-objective optimization. Non linear and non traditional techniques of optimization. Design for reliability, reliability based optimization.Stability Analysis: Beam column, buckling of frames. Lateral buckling of beams, torsional buckling, energy criterion and energy based methods, dynamic stability

Learning Resources

Text Books

1. Timoshenko and Goodier - Theory of Elasticity, McGraw-Hill Publications
2. S. Crandall, N. Dahl and T. Lardner - Mechanics of Solids, McGraw Hill Publications
3. Anil K Chopra – Dynamics of Structures Theory and Applications to Earthquake Engineering, Prentice-Hall Publications

4. R.W Clough and J Penzin – Dynamics of Structures, McGraw Hill Publications
5. R.C. Roy - Structural Dynamics an Introduction to Computer Methods, John Wiley & Sons Publications
6. S. Timoshenko and W. Krieger, Theory of Plates and Shells, Mc Graw Hill.
7. Ansel C. Ugural, Stresses in Plates and Shells, Mc Graw Hill
8. Chandrashekhara K., Analysis of Plates, New Age International Edition
9. J.N. Reddy – An Introduction to the finite element method – Tata McGraw Hill Publishing Co. Ltd

Course Contents - HYDRAULIC ENGINEERING

Module I - Water Resources Systems and Hydrologic Modeling

Water resources systems analysis, design and management for water supply, irrigation,drainage, hydropower, food control, droughts.Surface and ground water hydrology, stochastic hydrology, physical and numerical modeling, use of finite difference, finite element and boundary element methods.

Module II - Computational Hydrosystems and Monitoring

Instrumentation and monitoring of hydraulic systems, computer simulation and optimization of hydrosystems.Computational fluid dynamics, coastal hydrodynamics, watershed management, application of numerical methods.

Module III - Groundwater Systems and Hydroinformatics

Ground water systems planning and management, ground water pollution investigation. Hydroinformatics, multi criterion decision support system, applications of ANN and GA.

Module IV - Advanced Spillway Hydraulics and Dam Break Modeling

Hydraulics of spillways and energy dissipators, pressure fluctuations in hydraulic jump, static and dynamic uplift pressures in stilling basins. Remote sensing and GIS applications, Dam break analysis using softwares.

Text Books

1. Principles of water resources planning and management – Goodman
2. Applied hydrology – Linsley Kolhar and Paulhas (McGraw Hill)
3. Computational fluid dynamics – Anderson
4. Neural network fundamentals with graphs, algorithms, applications – Bose N.K. and Liang P (McGraw Hill)
5. Practical handbook of GA applications, Vol I – L. Chambers (CRC Press)

Course Contents - GEOTECHNICAL ENGINEERING

Module I - Advanced Geotechnics and Special Foundation Systems

Advanced Geotechnical Engineering

Stress distribution under earth embankments and evaluation of settlement profile. Field problems to monitor movement of slopes, foundations, etc.

Advanced Foundation Engineering

Foundations in difficult soils: expansive soils, chemically aggressive environment, soft soils,fill, regions of subsidence.

Module II - Rock Engineering and Geotechnical Earthquake Analysis

Rockmechanics and Tunelling

Deformation characteristics of rocks and its measurement. Instrumentation, Underground excavation and subsidence. Bearing capacity of homogeneous as well as discontinuous rocks.

Soil Dynamics and Geotechnical Earthquake Engineering Soil behaviour under dynamic loads. Seismic response, strong ground motion, its parameters and their estimation, seismic hazard analysis, local site effects and design ground motion, seismic slope stability

Module III - Geotechnical FEM and Geoenvironmental Systems

Finite Element Methods in Geotechnical Engineering

Stress deformation analysis: One-, Two,Three-dimensional formulations; Discretization;

Analysis of foundations, dams, underground structures and earth retaining structures.

Geoenvironmental Engineering Landfills, in ash ponds and tailing ponds, and in rocks. Detection, control and remediation of subsurface contamination; Engineering properties and geotechnical reuse of waste.

Module IV - Advanced Soil Structure Interaction and Infrastructure Geotechnics

Soil Structure Interaction

Elastic and plastic analysis of stress distribution on yielding bases. Analysis of conduits.

Interaction analysis of piles and pile groups. Elastic continuum and elastoplastic analysis of piles, Non-linear load-deflection response.

Geotechnics for Infrastructure Exploration studies for different Infrastructure Projects, Investigation reports, Analysis and required measures

Text Books

1. Aki K and Richards P G (2002), Quantitative Seismology, University Science Books
2. Bowles J E (1996), Foundation Analysis and Design, McGraw Hill.
3. Das B M (1997), Advanced Soil Mechanics, Taylor and Francis.
4. Das B M (1993), Principles of Soil Dynamics, Brooks/Cole
5. Coduto D P (2001), Foundation Design: Principles and Practices, Prentice -Hall

6. Kaniraj S R (1988), Design Aids in Soil Mechanics and Foundation Engineering, Tata McGraw Hill

7. Poulos H G and Davis E H (1980), Pile Foundation Analysis and Design, John Wiley and Sons

8. Koerner R M (1997), Designing with Geosynthetics, Prentice Hall

9. Karl Terzaghi (1954), Theoretical Soil Mechanics, Chapman and Hall,.

10. Rock Mechanics in Engineering Practice: Stag and Zienkiewez, John Willey & SonsJ.C. Jagger and N.G.W. Cook(1971), Fundamentals of Rock Mechanics, Methuen and Co., London.

11. Sarsby R (2000), Environmental Geotechnics, Thomas Telford

12. Hsai-Yang Fang, Introduction to Environmental Geotechnology, CRC Press.

13. Kramer S L (1996), Geotechnical Earthquake Engineering, Prentice Hall

14. Prakash Shamsher and Puri V K (1988), Foundations for Machines; Analysis and Design, John Wiley and Sons

15. Wolf J P (1985), Dynamic Soil-Structure Interaction, Prentice-Hall

Course Contents - ENVIRONMENTAL ENGINEERING

Module I - Water Treatment

Design period, water demand, water quality parameters, water quality Standards as per IS 10500-2012; Water treatment: aeration, sedimentation: plain chemical assisted, coagulation and flocculation, filtration, disinfection; water distribution system, ESR; Packaged WTP in townships; Government of India initiatives such as SMART city mission, Jal Jeevan Mission and AMRUT mission for improvement of infrastructure sector

Module II - Wastewater Treatment

Wastewater sources and types, importance of sanitation infrastructure, wastewater collection and conveyance, effluent discharge standards as per CPCB norms. Wastewater treatment: preliminary, primary, secondary and tertiary treatment; secondary treatment (suspended and attached growth systems): Activated sludge process (ASP), Up-flow anaerobic sludge blanket (UASB), sequencing batch reactor (SBR), membrane bio reactors (MBR), moving bed bio reactor (MBBR), fluidized membrane bio reactor (FMBR), packed bed reactor (PBR), trickling filter, RBC, Activated Biofilters. Sludge management: sludge characteristics, sludge digestor, sludge dewatering, sludge drying beds, sludge incineration, sludge disposal/ reuse

Module III - Municipal Solid Waste Management

Waste Management -Sources, Classifications, Characteristics, generations, on-site handling and storage, collection, transfer, Theory of composting, Bio-methnation, anaerobic digestion, incineration, Pyrolysis, refused derived fuel (RDF), landfills, leachate management, recycling and disposal techniques of Municipal Solid Waste (MSW), solid waste management rules 2016.

Module IV - Air pollutants

Air pollutants: sources and classification, Meteorological parameters and measuring instruments, air sampling, ambient air quality and emission standards, National Ambient Air Quality Standards (NAAQS) 2009, air pollution indices. Particulate emission control: Settling chamber, inertial separators, adsorption, absorption, bioscrubbers, biofilters, fabric filters, electrostatic precipitator. Control of gaseous pollutants from stationary sources: Absorption, adsorption, incineration, carbon sequestration. Indoor air quality.

Text Books

1. Water Supply Engineering, S. K. Garg, Khanna Publishers, New Delhi.
2. Water Supply and Sanitary Engineering, G. S. Birdie and J. S. Birdie, Dhanpat Rai Publishing Company, New Delhi.
3. Environmental Engineering-1: Water Supply Engineering, B. C. Punmia, Ashok Jain and Arun Jain. Laxmi Publications (P) Ltd.
4. Water Supply Engineering, Harold Eaton Babbit & James Joseph Doland, Tata McGraw Hill.
5. Waste Water Treatment & Disposal, Metcalf & Eddy, McGraw Hill Education (India) Private Limited
6. Environmental Engineering, Peavy Rowe, McGraw Hill Education (India) Private Limited
7. Sewage Disposal & Air Pollution Engineering, S. K. Garg, Khanna Publication
8. Wastewater Treatment for Pollution Control and Reuse, Arceivala and Asolekar, McGraw Hill Education (India) Private Limited
9. Integrated Solid Waste Management: Engineering Principles and Management Issues, George Tchobanoglous, Hilary Theisen, Samuel Vigil, Tchobanoglous George, Vigil Samuel, McGraw-Hill Companies, Incorporated.
10. Air Pollution, M. N. Rao, H. V. N. Rao, McGraw Hill, 2004.

Course Contents - Concrete Technology

Course Objectives: The course aims to:

- To develop an advanced, research-oriented understanding of cement chemistry, hydration mechanisms, special concretes, durability, and service life behavior of concrete systems.
- To build doctoral-level competence in sustainable concrete technologies, advanced material characterization, digital construction (3D printing), non-destructive testing, and performance-based design for innovative research and infrastructure applications

Module I - Cement Chemistry, Hydration and Binder Systems

Cement manufacturing processes and clinker chemistry, cement hydration mechanisms and kinetics, hydration as a function of binder composition, time and curing conditions, microstructure development and pore structure evolution, special cements and blended binders, alkali-activated binders and geopolymer systems, performance-based binder design, maturity concept, and hydration modeling.

Module II - Admixtures, Rheology and Fresh Concrete Technology

Mineral admixtures such as fly ash, GGBS, silica fume and metakaolin, chemical admixtures and compatibility issues, interaction mechanisms between cement–admixture systems, rheology of cementitious materials, yield stress, viscosity and thixotropy, fresh property control and performance modeling, 3D printing of concrete including printability, buildability, pumpability and digital construction

Module III - Special Concretes and Mechanical Behavior

Special concretes including fiber reinforced concrete, self-compacting concrete, high performance and ultra-high-performance concrete, foam and lightweight concrete, polymer modified concrete, mechanical properties of concrete, time-dependent behavior including creep mechanisms and shrinkage mechanisms, microstructural basis of mechanical performance

Module IV - Durability, Deterioration and Corrosion

Concrete deterioration mechanisms such as sulphate attack, chloride ingress, alkali–silica reaction, alkali–carbonate reaction, freeze–thaw damage and acid attack, transport mechanisms in concrete, electrochemical corrosion mechanisms, carbonation-induced and chloride-induced corrosion, corrosion prevention and control methods, durability-based design and service environment modeling

Module V - Service Life, Sustainability, Inspection and NDT

Service life estimation of reinforced concrete, probabilistic and deterministic service life models, sustainability of concrete including carbon footprint, life cycle assessment and circular economy concepts, sustainable concrete pavements, curing technologies including steam curing, membrane curing and internal curing, methods for inspection of concrete structures, current concrete NDT practices in India, structural health monitoring, and condition assessment

Reference Books

1. Concrete Technology – Santhakumar, Oxford University Press
2. Concrete Technology – A. M. Neville & J. J. Brooks
3. Properties of Concrete – Murdock
4. Properties of Concrete – P. K. Mehta
5. Concrete Technology – M. S. Shetty
6. Fiber Reinforced Cement Composites – P. N. Balguru & P. N. Shah

Text Books

1. Advanced Concrete Technology — John Newman & Ban Seng Choo
2. Cement and Concrete Chemistry — Frederick H. Wittmann
3. Concrete Permeability and Durability Performance: From Theory to Field Practice — Yukio Hama, Hideki Ishida, Bernhard Lehner
4. Durability of Concrete and Cement Composites — R. J. F. Silva, M. A. T. van Duinen, P. M. A. van Maas (Editors)
5. Concrete Durability: Understanding, Investigation and Repair — John P. Broomfield
6. Rheology and Processing of Construction Materials — Rudy J. M. Wolfs, Claudio Pellegrino

Savitribai Phule Pune University **Ph. D. Course Work (Engineering)**		
MEC-SPC1 - Mathematics for Mechanical Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Prerequisite Courses :

1. Differentiation, Integration, Maxima and Minima, Matrices and Determinants

Course Objectives: The course aims to cover foundational and emerging topics instrumental for analysis, modeling, simulation, and optimization relevant to mechanical systems.

- To develop a deep understanding of vector spaces, inner product spaces, and matrix decompositions to effectively model complex mechanical systems.
- To equip researchers with analytical and numerical techniques, such as Fourier series and transform methods, to solve heat, wave, and diffusion equations encountered in mechanical engineering.
- To provide expertise in numerical solutions for systems of linear equations and ordinary differential equations using methods like Runge-Kutta and Taylor's series for engineering problem-solving.
- To formulate mathematical representations of stress and strain in solids and fluids using tensor analysis and constitutive relations.
- To utilize calculus of variations, optimal control theory, and advanced nonlinear programming techniques for the modeling and optimization of engineering designs.

Course Contents

Module I - Advanced Linear Algebra and Matrix Theory

- Vector spaces, inner product spaces, and orthogonality.
- Eigenvalues, eigenvectors, and diagonalization of matrices.
- Matrix decompositions and their applications in mechanical system modeling.

Module II - Applied Partial Differential Equations

- Classification and solution techniques for PDEs (Fourier series, transform methods).
- Analytical and numerical methods for heat, wave, and diffusion equations.
- Boundary and initial value problems encountered in mechanical engineering.

Module III - Numerical Methods

- Numerical solution of system of linear equations: Gauss elimination method, Numerical Method for finding Eigen value and Eigen vector.
- Numerical solutions of ordinary differential equation: Euler's method, Modified Euler's method, Runge–kutta method.
- Taylor's series method, Predictor-corrector method, Applications to Engineering problems.

Module IV - Continuum Mechanics and Tensor Calculus

- Fundamentals of vector and tensor analysis.
- Mathematical formulation of stress and strain tensors in solids and fluids.
- Balance equations and constitutive relations for mechanical systems.

Module V - Optimization and Mathematical Modeling

- Variational methods, calculus of variations, and optimal control theory.
- Mathematical modeling of mechanical systems for design and analysis.
- Advanced optimization techniques, including multi-objective and nonlinear programming.

Learning Resources

Reference Books:

1. Advanced Linear Algebra by Steven Roman
2. Partial Differential Equations by V. P. Mikhailov.
3. An Introduction to Partial Differential Equations by Y. Pinchover & J. Rubenstein.

Savitribai Phule Pune University **Ph. D. Course Work (Engineering)**		
MEC-SPC2 - Advances in Mechanical Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

- Any THREE of the following topics or modules can be covered as part of the course.

Course Objectives: Upon completion of this course, the scholar will be able to:

1. Critically Analyze Emerging Technologies in Mechanical Engineering
2. Formulate Advanced Mathematical & Computational Models
3. Evaluate Sustainable & Green Engineering Practices
4. Master Advanced Experimental & Characterization Techniques
5. Synthesize Interdisciplinary Research Trends

Course Contents

Module I - Convective Heat Transfer

- Fully developed flows, exact and similarity solutions
- Boiling and condensation, special topics

Module II - Mass Transfer

- Mass transfer
- Droplet vaporization

Module III - Combustion

- Premixed and Diffusion flames
- Advanced combustion modeling (chemical kinetics)
- Engine performance optimization

Module IV - Computational Fluid Dynamics – I (CFD – I)

- Finite volume algorithm, up-winding,
- Solution of pressure field on Cartesian meshes

Module V - Turbulence

- Governing equations, Free shear flows, Near wall behavior,

- Energy spectrum, Turbulence models

Module VI - Vibrations

- Multi-degree freedom systems,
- Approximate and numerical methods,
- Continuous systems, Nonlinear systems

Module VII- Acoustics

- Wave propagation
- Generation/transmission of sound, noise control

Module VIII - Fracture Mechanics

- Linear Elastic Fracture Mechanics,
- Elastic Plastic Fracture Mechanics,
- Fracture Mechanisms in Metals

Module IX- Advanced Topics in Refrigeration and Cryogenics

- Refrigeration applications in preservation of Food, transport by trucks and containers;
- Railway cars; Marine Refrigeration; Fans and Blowers, Sound Control.
- Construction of psychrometric charts, enthalpy deviation curves (Any two)

Module X - Advanced Theory of Elasticity (3-dimensional problems):

- Theories of Stress and strain,
- Transformation of stress and strain, Linear stress-strain – temperature relations,
- Applications of energy methods, Torsion, Bending, Plates

Module XI - Robotics

- Kinematics, Dynamics, Trajectory, Control

Module XII - Advanced Topics in I C Engines

- Engine Emissions & Control, Engine Electronics, Modelling Real Engine Flow and Combustion Process, Fuel/Air Mixture Requirements (Any two)

Module XIII - Finite Element Methods

- Thermal analysis (temperature effects), 2D, 3D elements,Contact analysis, Non-linear static analysis

Module XIV - Micro Electro Mechanical Systems (MEMS)

- From Microphysics to Macrophysics, Thermodynamics of Microstructures, Reliability of MEMS

Module XV - Bio-medical device design

- Applications, FDA approval procedures, A Certification

Savitribai Phule Pune University **Ph. D. Course Work (Engineering)**		
ETC-SPC1 - Mathematics for Electronics & Telecommunication Engineering **ETC-SPC1 - Mathematics for Electronics Engineering**		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Course Objectives:

1. To provide a deep understanding of vector spaces, matrix factorizations (such as QR and SVD), and eigenvalue problems essential for applications in MIMO systems and signal processing.
2. To equip students with the ability to model and analyze communication channels and noise using probability spaces, random processes, and Markov chains.
3. To develop proficiency in using Fourier, Laplace, Z, and Wavelet transforms for advanced signal representation, filtering, and time-frequency analysis.
4. To enable the application of classical, convex, and evolutionary optimization techniques (like Genetic Algorithms or PSO) to solve complex problems in machine learning and antenna design.
5. To provide the mathematical tools necessary to solve differential equations and conduct stability analysis for circuit theory, control systems, and electromagnetic wave propagation

Course Contents

Module I - Advanced Linear Algebra and Matrix Theory

Vector spaces, subspaces, bases, and dimension
Eigenvalues, eigenvectors, and diagonalization
Hermitian, unitary, and normal matrices
Matrix factorizations (QR, SVD, Schur decomposition)
Applications in signal processing, MIMO systems, coding theory

Module II - Probability, Random Processes, and Stochastic Analysis

Probability spaces, conditional probability, Bayes' theorem
Random variables and distributions (Gaussian, Poisson, Rayleigh, etc.)
Expectation, variance, correlation, covariance
Random processes: stationarity, ergodicity, power spectral density
Markov chains and Markov processes
Stochastic calculus and Wiener process basics
Applications in communication channels, noise analysis, queuing models

Module III- Transform Methods and Functional Analysis

Fourier series and Fourier transform
Laplace transform, Z-transform, Hilbert transform

Wavelet transform and time-frequency analysis
Distributions and generalized functions (Dirac delta, impulse functions)
Normed linear spaces, Hilbert and Banach spaces
Applications in signal representation, filtering, spectral analysis

Module IV - Optimization Techniques

Classical optimization (unconstrained and constrained)
Convex sets and convex optimization
Lagrange multipliers, Kuhn-Tucker conditions
Numerical optimization: gradient descent, Newton's method, quasi-Newton methods
Evolutionary and heuristic optimization (genetic algorithms, PSO)
Applications in adaptive filtering, machine learning, antenna design

Module V - Differential Equations and Dynamical Systems

Ordinary differential equations (ODEs): linear and nonlinear
Partial differential equations (PDEs): wave, heat, diffusion, and Laplace equations
Stability analysis: Lyapunov stability, bifurcation theory
Dynamical systems and chaos theory
Applications in circuit theory, control systems, electromagnetic wave propagation

Learning Resources

Reference Books:

1. Papoulis & Pillai – Probability, Random Variables and Stochastic Processes
2. Stark & Woods – Probability and Random Processes with Applications to Signal Processing
3. Kreyszig – Advanced Engineering Mathematics
4. Boyd & Vandenberghe – Convex Optimization
5. Oppenheim & Schafer – Discrete-Time Signal Processing
6. Strang – Linear Algebra and Its Applications
7. Haykin – Communication Systems

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
ETC-SPC1 -Advances in E & TC Engineering **ETC-SPC1 -Advances in Electronics Engineering**		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

- Any THREE of the following topics or modules can be covered as part of the course.

Course Contents

Module I- Microelectronics and VLSI

Microelectronic devices, characteristics, mathematical modeling, performance parameters, design aspects, parasitics, integration issues, layout rules, optimization techniques

Module II - RFIC Design

RF Amplifiers, characteristics, mathematical models, power relations, stability considerations, stability circles, unconditional stability, stabilization methods, designs, circles, circles

Module III - Mixed Signal Analysis

Signal integrity, techniques, equivalent models, characteristics, limitations, mixed signal processing, simulation, physical parameters.

Module IV - RF Systems

The techniques of RF amplifier, mixer and local oscillator designs, Advanced YIG and narrow band filters, amplifiers, Transmission line design, Design challenges in satellite frequency bands

Module V- Microwave and Antennae

Microwave sources, Passive devices, MMIC, MMIC fabrication techniques, Thick and Thin film technologies and materials, Microstrips, Microwave antennae.

Module VI - Coding and Modulation Techniques in Communication

Digital communication system architectures, Source coding, Channel coding, Performance measures of communication systems, PLD based system implementations and related issues.

Module VII- Communication Network

Various IEEE standards, Performance issues, Trade-offs, Network architectures, Security algorithms with their performance measures.

Module VIII -Wireless & Broadband Communication

IEEE/ITU/ ETSI communication standards and specifications, various trade-offs in functionality, implementation, Transmitter/Receiver architectures and related issues, Wireless embedded approach, Antennae and front end design issues.

Module IX - Advanced Topics in Signal Processing

Modeling different Signals and systems, various transforms, System design and Implementation issues, DSP architectures and related issues, Evaluation parameters for the various applications.

Module X- Image Processing & Pattern Recognition

Image representation formats, noise, processing techniques, Performance measures, various algorithms, Pattern classifications and recognition techniques, Biometrics.

Module XI- Speech Processing

Speech recognition and synthesis techniques, modeling the speech signal, various algorithms, trade-offs and implementation issues.

Module XII- Processor Architectures

Design philosophy of RISC, CISC, Multi-core, Various processor architectures, Design of microcontroller CPU.

Module XIII- Programmable Architectures and Memories

HDL programming, PLDs, floating point arithmetic, multipliers, modeling a sequential machine, Barrel shifter, HDL models for memories and buses.

Module XIV - System on Chip and MEMs

Chip architecture, Clock & power related issues, SRC, DRC, I/O architectures, Wire parasitic, Design validation, MEMs.

Module XV- Modern Control Theory

Control mechanisms and their modeling, Implementation aspects and related trade-offs, various applications, Selection criteria's of control systems for various applications, Performance evaluation techniques

Module XVI Human Machine Interface

Different techniques used for HMI, Algorithms, Related issues and constraints, Performance issues, Applications

Module XVII - Machine Vision

Human vision, Expert systems, Algorithms, Implementation issues and trade offs, Performance measures and analysis.

Module XVIII - Biomedical Engineering

Biomedical Signals, Biomedical Systems, Analysis, Implementation issues, Performance measures

Module XIV - Nano Technology

Present devices and materials, Advance materials such as Carbon nano tubes etc., advance devices, constraints, applications, Trade offs.

Learning Resources

Text Books

1. M.J. Roberts, “Signals and Systems”, Tata McGraw Hill Publications, 2003.
2. M. Burns, “Introduction to Mixed Signal IC Test and Measurement”, Oxford University Press Publications, New York.
3. Xilinx, “The Programmable Logic Data Book”, Xilinx, California.
4. Hu, Yu Hen, “Handbook of Neural Network Signal Processing”, CRC Press Publications.
5. Yacoub M.D., “Wireless Technology”, CRC Press Publications.
6. Gold B., “Speech and Audio Signal Processing”, John Wiley Publications.
7. Kuo B.C., “Digital Control System”, Sounders College Publications, New York.
8. Comer “Digital Logic and State Machine Design”, Sounders College Publications, New York.
9. Prokis J.G., “Digital Signal Processing”, PHI Publications.
10. Alley, Charles L, “Micro Electronics”, McGraw Hill Publications.
11. Ha, Tri T., “Digital Satellite Communication”, McGraw Hill Publications.
12. Peebles, “Probability and Random Signals”, McGraw Hill Publications.
13. Balanis, “Antenna Theory analysis and Design”, John Wiley Publications.
14. Gray R.P.,” Analysis and Design of Analog ICs”, John Wiley Publications.
15. Tompkins J.W., “Biomedical Digital Signal Processors”, PHI Publications.
16. Collin E.R., “Foundations for Microwave Engineering”, McGraw Hill Publications.
17. Freeman R.L., “Radio System Design for Telecommunication”, John Wiley Publications.
18. Kronsjo L., “Advances in Parallel Algorithm”, Blackwell Scientific Publication, London.
19. Xavier, Eugune S.P., “Statistical Theory of Communication”, New Age International Publication.
20. Baker R.J., “CMOS: Circuit Design, Layout and Simulation”, IEEE Press Publication.
21. McGillen C.D., “Continuous and Discrete Signal and System Analysis”, Oxford University Press.
22. Russ J.C., “The Image Processing Handbook”, CRC Press Publications.
23. Franssila S., “Introduction to Micro fabrication”, John Wiley Publications.
24. Park J., “Practical Embedded Controllers”, Elsevier Publications, Amsterdam.
25. Kabatiansky G., “Error Correcting Coding and Security for Data Network
26. Lee K., “Semiconductor Device Modeling For VLSI”, PHI Publications.
27. Maxfield C.M., “The Design Warriors Guide to FPGA”, Elsevier Publications, Amsterdam.

28. Carsten Steger, Markus Ulrich, Christian Wiedemann, “Machine Vision

29. Algorithms and Applications”, Wiley-VCH, Weinheim Publications.

30. Pires, J. Norberto, “Human Machine Interface for Industrial Robotic Cells”, Springer Publications.

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
ELE-SPC1 - Mathematics for Electrical Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Course Objectives:

1. To equip students with mathematical tools in linear algebra, optimization, and probability to analyze and model power system restructuring and electricity market dynamics.
2. To develop proficiency in Fourier analysis, differential equations, and numerical methods to solve problems in power electronics and drive systems.
3. To enable students to apply signal processing and statistical techniques to analyze and mitigate power quality issues in electrical systems.
4. To foster skills in optimization, control theory, and computational methods for designing intelligent control systems using neural networks and genetic algorithms.
5. To provide a strong foundation in advanced numerical and computational techniques for solving complex problems across power systems, electronics, and control applications.

Course Outcomes:

After successful completion of the course, learner will be able to:

- CO1: Explain how linear algebra, optimization techniques, and game theory are applied to model power tariffs, electricity market pricing, and investment decisions in power system restructuring.
- CO2: Apply Fourier analysis and differential equations to analyse harmonic distortions and design control systems for multilevel inverters in variable speed drives.
- CO3: Analyze power quality issues, such as voltage sags and harmonics, using wavelet transforms and statistical methods, interpreting results in the context of IEEE standards.
- CO4: Evaluate the performance of a neural network-based control system by applying optimization techniques and state-space models to ensure accurate system identification and control.
- CO5: Develop a numerical model using finite element methods or Monte Carlo simulations to solve a complex problem in power systems or intelligent control, optimizing for computational efficiency.

Course Contents

Module I - Linear Algebra

Linear algebra for power tariff and pricing models: matrix operations, eigenvalues, and eigenvectors for network analysis. Optimization techniques: linear programming, non-linear programming, and

constrained optimization for investment option comparison and spot pricing. Game theory basics: Nash equilibrium and cooperative games for electricity market models. Probability and statistics: expected value, variance, and stochastic processes for reactive power pricing and market uncertainties.

Module II - Fourier Analysis

Fourier series and transforms for harmonic analysis in converters and inverters. Differential equations: ordinary differential equations (ODEs) for modelling switching devices and chopper circuits. Z-transforms and discrete-time systems for digital control in variable speed drives. Matrix transformations and Park's transformations for modelling multilevel inverters. Numerical methods: Newton-Raphson and Runge-Kutta methods for solving non-linear equations in advanced control techniques.

Module III - Time-Frequency Analysis

Short-Time Fourier Transform (STFT) and wavelet transforms for analyzing voltage sags, swells, and transients. Statistical methods: probability distributions, hypothesis testing, and confidence intervals for power quality monitoring (IEEE Std. 1159). Harmonic analysis: Fourier transforms and spectral analysis for waveform distortion and harmonic mitigation. Linear algebra: singular value decomposition (SVD) for identifying resonance in K-rated transformers. Filtering techniques: design of digital filters for flicker and transient control.

Module IV - Linear and Non-Linear Optimization

Gradient descent and Lagrange multipliers for neural network training. Differential equations and state-space models for system identification and control in fuzzy and neuro-fuzzy systems. Probability and clustering: Bayesian methods and k-means for pattern recognition and classification in ANNs. Graph theory: adjacency matrices and connectivity for knowledge-based systems. Genetic algorithms: mathematical formulation of selection, crossover, and mutation for optimization in control systems.

Module V - Numerical Linear Algebra

Iterative methods (e.g., Gauss-Seidel, conjugate gradient) for large-scale power system matrices. Finite difference and finite element methods for modeling electromagnetic fields in power electronics and quality analysis. Monte Carlo simulations for uncertainty analysis in power markets and intelligent control. Interpolation and approximation: polynomial and spline interpolation for data-driven modeling in electrical systems. Computational complexity: analysis of algorithms for real-time applications in control and monitoring.

Learning Resources

Text Books:

1. Kreyszig, E. Advanced Engineering Mathematics (10th ed.). Wiley, 2011.
2. Xavier, C. G. R., & Raja, J., Applied Mathematics for Electrical Engineers (1st ed.). New Age International, 2018.
3. Oppenheim, A. V., & Willsky, A. S. Signals and Systems (2nd ed.). Pearson, 1997.
4. Chapra, S. C., & Canale, R. P., Numerical Methods for Engineers (7th ed.). McGraw-Hill, 2014

Reference Books:

1. Luenberger, D. G., Optimization by Vector Space Methods (1st ed.). Wiley, 1997.

2. Rao, R. M., & Bopardikar, A. S., Wavelet Transforms: Introduction to Theory and Applications (1st ed.). Pearson, 1998.

3. Haykin, S., Neural Networks and Learning Machines (3rd ed.). Pearson, 2008.

4. Golub, G. H., & Van Loan, C. F., Matrix Computations (4th ed.). Johns Hopkins University Press 2013.

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
ELE-SPC2 - Advances in Electrical Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Any THREE of the following topics or modules can be covered as part of the course.

Course Objectives:

1. To expose scholars to advanced theoretical and applied areas of electrical engineering with emphasis on global and Indian research trends.
2. To equip scholars with knowledge of cutting-edge technologies in power, control, automation, energy systems, and interdisciplinary applications.
3. To develop strong research capabilities in analyzing, modeling, simulating, and designing innovative solutions to complex problems.
4. To foster critical thinking, innovation, and sustainability-oriented approaches in doctoral research.
5. To prepare scholars for contributing to both academia and industry through high-impact research publications and technology development.

Course Outcomes: After successful completion of the course, scholars will be able to:

1. Critically analyze and synthesize advanced concepts in power systems, power electronics, and intelligent control.
2. Apply AI, data analytics, and simulation techniques to solve emerging challenges in electrical engineering.
3. Conduct in-depth research in next-generation technologies such as EVs, smart grids, HVDC, and energy storage systems.
4. Identify and pursue interdisciplinary research opportunities in automation, Industry 4.0, and sustainable technologies.
5. Formulate, present, and defend original research ideas contributing to advancements in electrical engineering

Course Contents

Module I - Advanced Power System and its Protection

Smart Grids: Introduction to Smart Grid, Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Concept of Robust & Self-Healing Grid, Present development & International policies in Smart Grid, Introduction to Smart Meters, Real Time Prizing, Smart Appliances, Automatic Meter Reading (AMR), Outage Management System (OMS)

Power System Protection: Fundamentals of digital and numerical relays: design, features, and applications in modern grids, Protection coordination in interconnected and smart grids with adaptive and wide-area schemes Synchro phasor technology (PMUs) and Wide Area Monitoring, Protection & Control (WAMPAC), Case studies of blackouts and system failures with lessons for advanced protection

References:

1. Ashok Jhunjhunwala, A. Srivastava, and R. Kumar, Smart Grid: Technology and Applications, PHI Learning.
2. C. L. Wadhwa, Electrical Power Systems, New Age International.
3. R. K. Rajput, Power System Engineering, Laxmi Publications.
4. S. R. Bhide, "Digital Power System Protection" (PHI Learning)
5. L. P. Singh, "Digital Protection" New Age International
6. 6. B. Ram, "Power System Protection and Switchgear" Tata McGraw Hill

Module II - Renewable Energy Systems

Renewable Energy Integration: Challenges of connecting solar, wind, and hybrid plants; methods of forecasting power, Power electronic interfaces and control strategies for efficient energy conversion and integration, Policies, regulations, and Indian case studies on renewable deployment and smart grid applications.

Energy Storage Systems: Battery storage, Pumped hydro and compressed air energy storage (CAES), and hybrid storage for grid balancing. Case studies on storage applications in smart grids and renewable-dominated Indian power systems.

References:

1. D. P. Kothari, K. C. Singhal, Rakesh Ranjan, Renewable Energy Sources and Emerging Technologies, PHI learning
2. Kumari Namrata, R. P. Saini, and D. P. Kothari, Solar Energy Systems, Springer
3. Rajkumar K, K. Gaayathry, Gobimohan, and P. Ravi Kumar, Renewable Energy Systems with Advanced Smart Grid Technologies
4. Ashwani Kumar, S.C. Srivastava, S.N. Singh, Renewable Energy Towards Smart Grid
5. “Indian Energy Scenario and Smart Grid Development”, a chapter in Advances in Clean Energy Technologies

Module III- Power Electronics

Wide-Bandgap Devices: SiC, GaN and advanced converter topologies for high-power applications, compact converters.

Power Converters: Multilevel converters, modular multilevel converters (MMC), and matrix converters. Reliability, thermal management, and protection of high-power converters, Bidirectional converters for energy storage systems and solid-state transformer applications

Power quality improvement: harmonic elimination, reactive power compensation, and active filtering

Emerging trends: solid-state transformers, DC grids, power electronics for electric mobility and future smart grids.

References:

1. M.S. Tyagi, Introduction to Semiconductor Materials and Device
2. M. H. Rashid (Adapted by Indian Authors), Power Electronics: Circuits, Devices and Applications, Pearson India.
3. N. Mohan, T. Undeland, W. Robbins (Indian Adaptation), Power Electronics: Converters, Applications and Design, Wiley India.
4. Rashid & S. K. Sharma, Simulation of Power Electronics and Electric Drives using MATLAB/Simulink, Narosa Publishing.
5. Anindya Dasgupta (IIST), Design and Control of Matrix Converters, detailing matrix-converter operation, voltage sag mitigation, and control strategies
6. Manchala Naini Raju et al. (CPRI review on MMC); Anindya Dasgupta on Matrix Converters

Module IV- Electric Mobility

Electric Mobility: powertrain topologies, energy flow management, and integration of auxiliary systems. Traction motors (BLDC, PMSM, SRM): modeling, control strategies, efficiency optimization, and regenerative braking techniques.

Battery Management Systems (BMS): SOC/SOH estimation methods, safety protocols, thermal management, and ultra/fast charging.

Charging Infrastructure: AC/DC chargers, smart and wireless charging technologies, and V2G-enabled systems. Standards, communication protocols, and interoperability for charging systems with case studies on India's EV charging landscape.

References:

1. C. S. Sharma & Kamaljit Sidhu – Electric and Hybrid Vehicles (Narosa Publishing House, New Delhi)
2. Ashok Jhunjhunwala and A. Srivastava, Electric Vehicles: Technology, Policy and Commercial Development, Springer India.
3. Dr. K. S. Suresh Kumar, Electric Vehicles and Control Systems, Universities Press (India).
4. S. Sivanagaraju & Ch. Sreenivasa Rao – Electric Vehicles (Pearson / PHI Learning, India)

5. Tarun Huria & B. K. Panigrahi – Battery Management Systems and Applications (CRC Press India)

Module V - Intelligent Control Systems

Advanced Control Methods: Introduction to robust and adaptive control system, design and implementation of adaptive, robust such as sliding mode control, H infinity & μ synthesis. Quantitative feedback theory (QFT), LMI based robust control. Introduction to fractional order robust control and event triggered robust control for uncertain, non-linear, and time-varying electrical systems.
Applications include power converters, electric drives, and power system stability enhancement.

Advanced Topics: Exploration of hybrid intelligent systems combining fuzzy, neural, and evolutionary approaches for complex decision-making systems. Real-time control (RTC) strategies and cutting-edge research in cyber-physical systems, self-healing grids, and autonomous electrical systems.

Model Predictive Control (MPC): Overview of MPC concepts & motivation, empirical & physics-based models, discrete time models, linear MPC, stability in MPC, robust & stochastic MPC, Hybrid MPC, learning MPC. Applications in high-performance electric drives, renewable-integrated power systems, and robotics for dynamic trajectory tracking.

References:

1. Kemin Zhou, John C. Doyle, Keith Glover, Robust and Optimal Control, Prentice Hall
2. Geir E. Dullerud, Fernando Paganini, A Course in Robust Control Theory-A Convex Approach, Springer
3. Michael Green, David J.N. Limebeer, Linear Robust Control, Prentice Hall
4. M. Gopal, Modern Control System Theory, New Age International.
5. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill.
6. BK. Ogata (Indian Adapted Edition), Modern Control Engineering, Pearson India.
7. Axaykumar Mehta & Brijesh Naik — Sliding Mode Controllers for Power Electronic Converters
8. Chitralekha Mahanta & Laxmidhar Behera, Intelligent Control Systems: Principles and Applications
9. Jitendra R. Raol & Ayyagari Ramakalyan-Control Systems: Classical, Modern, and AI-Based Approaches (CRC Press)

Module VI- Automation & Robotics

Industrial Automation Foundations: PLCs, SCADA, Distributed Control Systems (DCS), and their deployment in electrical power and manufacturing environments, HMIs, AC-DC drives & GUI.

Robotics Fundamentals: System architecture, kinematics, dynamics, trajectory planning, and control of robotic manipulators.

Sensing & Actuation: Use of sensors, actuators, vision systems, and embedded controllers for automation and robotic tasks.

Applications: Robotics-driven power system inspection, smart grid maintenance, renewable energy automation, and electric mobility support.

Emerging Trends: Self-healing automated systems, autonomy in power electronics, robotic assistance in maintenance, and factory automation innovations.

References

1. C. Kuo & Farid Golnaraghi (Indian Edition), Automatic Control Systems, Wiley India.
2. D. Subbarao & B. V. Ramana, Industrial Automation: Concepts and Practical Perspectives, PHI Learning.
3. R. K. Rajput, Robotics and Industrial Automation, Laxmi Publications.
4. Industrial Automation Solutions for PLC, SCADA, Drive and Field Instruments by Sanjay B. Katariya
5. K. R. Guruprasad Robotics: Mechanics and Control, PH india

Module VII - Research Frontiers & Sustainable Innovations in Electrical Engineering

Energy Storage Innovations: Hydrogen fuel cells, supercapacitors, hybrid storage, and India's National Hydrogen Mission.

Smart Microgrids & Building Energy Management: Demand-side management, prosumers, smart meters, net metering policies.

Sustainable Energy Technologies: Green hydrogen, carbon capture, utilization & storage and bioenergy systems for India's future

Future research frontiers: digital twins, IoT/blockchain-enabled grids, and interdisciplinary approaches to sustainable power.

References:

1. Ashok Jhunjhunwala, Energy Storage Technologies for Indian Power Sector, Springer India.
2. R. K. Rajput, Renewable Energy Sources and Emerging Technologies, PHI Learning.
3. Suddhasatwa Basu (Ed.) – Recent Trends in Fuel Cell Science and Technology, Springer
4. B. Viswanathan & M. Aulice Scibioh – Fuel Cells: Principles and Applications (CRC Press)
5. Baseem Khan, Sanjeevikumar Padmanaban, Hassan Haes Alhelou, Om Prakash Mahela & S. Rajkumar (Eds.) – Artificial Intelligence-Based Energy Management Systems for Smart Microgrids, CRC Press (2022)
6. Siddharth Jain, Aboli Atul Kulkarni & Yashwant Sawle – Chapter: Overview of Energy Management Systems for Microgrids and Smart Grid, in Planning of Hybrid Renewable Energy Systems, Electric Vehicles and Microgrid (Springer)

Module VIII - HVDC & FACTS Devices

Detailed study of FACTS controllers: SVC, STATCOM, TCSC, SSSC, UPFC, and IPFC. Developments in VSC-HVDC, Modular Multilevel Converters (MMC), and Multi-terminal DC grids for large-scale renewable integration.

Recent advances: FACTS controllers (STATCOM, UPFC, hybrid FACTS) for voltage stability, oscillation damping, and power quality improvement.

Applications: AI/ML and digital twins for adaptive control, fault diagnosis, and predictive maintenance in HVDC/FACTS.

Case studies: Indian and global HVDC & FACTS projects with emphasis on smart grid and future DC grid applications.

References:

1. K. R. Padiyar, Facts Controllers in Power Transmission and Distribution by, New Age International Pvt. Ltd.
2. HVDC Power Transmission Systems by K. R. Padiyar, New Age International / New Academic Science
3. K. Meenendranath Reddy, D. Umendra & P. Nagatimmaiah, Fundamentals of HVDC and FACTS in Power Systems, Ink of Knowledge
4. Anshuman Shukla, "Multilevel Converter Topologies for STATCOMs" in Static Compensators (STATCOMs) in Power Systems, Springer (2015)

Module IX - Soft Computing Techniques

Fundamentals of Soft Computing: Hard computing vs. soft computing, Characteristics of ANN, Fuzzy Logic, and Genetic Algorithms, Scope and relevance in engineering research

Artificial Neural Networks: Neuron models, activation functions, learning paradigms (supervised, unsupervised, reinforcement), Architectures: Multilayer Perceptron's, RBF Networks, Self-Organizing Maps, **Training algorithms:** Backpropagation, Gradient Descent, and advanced variants, Applications: load forecasting, fault classification, power system modelling, pattern recognition

Fuzzy Logic System: Fuzzy sets, membership functions, and linguistic variables, Fuzzy inference systems (Mamdani, Sugeno), Fuzzy control and decision-making strategies

Genetic Algorithms and Evolutionary Computing: Biological basis, population, fitness functions, selection, crossover, mutation, Multi-objective optimization and constrained optimization, Hybridization with ANN and fuzzy systems

References

1. Rajasekaran & Vijayalakshmi Pai – Neural Networks, Fuzzy Logic, and Genetic Algorithms (PHI)
2. S.N. Sivanandam, S. Sumathi, S.N. Deepa – Principles of Soft Computing (Wiley India)
3. Satish Kumar – Neural Networks: A Classroom Approach (Tata McGraw Hill)

4. B. Yegnanarayana – Artificial Neural Networks (PHI Learning)

5. Kalyanmoy Deb – Optimization for Engineering Design: Algorithms and Examples (PHI)

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
CHE- SPC1- Mathematics for Chemical Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Prerequisite Courses :

1. Differentiation, Integration, Maxima and Minima, Matrices and Determinants

Course Objectives: The course aims to:
To solve first order linear, non linear partial differential equations, second order partial differential equations, Solve differential equations using Laplace Transforms.

Course Outcomes: Upon successful completion of this course, students will be able to:

- CO 1: .Solve first and higher order differential equations
- CO 2: Apply numerical techniques for solving mathematical problems
- CO 3: Solve first order linear and non-linear partial differential equations
- CO 4: Develop problem solving skills using mathematical transforms
- CO 5: Apply statistical analysis and optimization techniques to solve real world problems

Course Contents

Module I - Differential equations

Solution of differential equations in series with reference to Bessel and Legendre equations, Elementary properties of Bessel and Legendre functions, Solution of differential equations by numerical methods, Euler's modified method, Runge-Kutta method

Module II - Numerical analysis

Roots of equation: The bisection method, the false-position method, fixed point iteration, the Newton-Raphson method, Gauss-Seidel method, Milne's method, LU decomposition, Muller's method, Approximation and round of errors, Truncation error

Module III - Partial differential equation

Formation and classification of partial differential equations, first order linear equations, standard forms of nonlinear equations, homogeneous linear equations with constant coefficients. Different methods for parabolic equations, hyperbolic equations and elliptic equations. Solution of partial differential equations of engineering interest by method of separation of variables.

Module IV - Transform Techniques

Laplace, Fourier transforms, Finite Fourier Transform, Z-transforms: Introduction, standard Z-transforms, properties of z-transforms, initial value and final value theorems, Inverse – Z-transforms, Inverse Z-transforms by power series method, partial fractions method and integral method, application to difference equations.

Module V - Statistics and Optimization

Statistical Preliminaries: Understanding the central tendencies of a time series. Explaining the data sets using data variance, covariance, regression, correlation coefficient, autocorrelation.

Linear systems with constraints, unconstrained nonlinear systems constrained nonlinear cases, Tabu Search, Simulated Annealing, Swarm Intelligence

Learning Resources

Text Books

1. B. V. Ramana, Higher Engineering Mathematics, Tata McGraw-Hill, 2006
2. B. S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 2012

Reference Books:

1. Erwin Kreyszig, Advanced Engineering Mathematics John Wiley & Sons., 2006
2. Peter O'Neil, Advanced Engineering Mathematics, Cengage Learning, 2012
3. M. D. Greenberg, Advanced Engineering Mathematics, Prentice Hall, 1998
4. Ron Larson, Elementary Linear Algebra, Cengage Learning, Inc, 2012
5. Thomas' Calculus George B. Thomas Pearson, 2014
6. N. Sneddon, The use of Integral Transform, McGraw Hill, New York, 1972.
7. L Debnath, Integral Transforms and their Applications CRC Press, Inc. 2nd Ed., 2015.
8. Jorge Nocedal and Stephen Wright; Numerical Optimization, Springer, 2nd edition, 2006
9. S. S. Rao, Engineering Optimization: Theory and Practice, Wiley, 4th Edition, 2009

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
CHE- SPC2 - Advances in Chemical Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Any THREE of the following topics or modules can be covered as part of the course.

Prerequisite Courses :

1. Basics of thermodynamics, reaction engineering, process control, modeling and simulation

Course Objectives: The course aims to:

- To familiarize the students with latest concepts and techniques in Chemical Engineering.
- The latest concepts will help the students to know what are the latest trends in chemical engineering which will help them in identifying the topic of research and further completion of their research work.

Course Outcomes: Upon successful completion of this course, students will be able to:

- CO 1: Apply the knowledge of thermodynamics to chemical processes
- CO 2: Select the catalyst and design the reactors for carrying out multiphase reactions
- CO 3: Design control systems for chemical processes
- CO 4: Model and simulate the systems to find optimized parameters
- CO 5: Apply concepts of artificial intelligence for solving chemical engineering problems

Course Contents

Module I - Advanced Chemical Engineering Thermodynamics

Classical thermodynamics and statistical thermodynamics, phase equilibria and chemical reaction equilibria; phase non-ideality measurement using advanced models viz. NRTL, activity coefficient model, etc.; Energy calculations, Multi reaction Equilibria; Combined Phase and Reaction Equilibria; Basics of statistical thermodynamics

Module II - Catalysis, Reactors and Reaction Engineering

Heterogeneous reactor analysis and design Special reactors, Molecular catalysis, Solid catalyst, supported catalyst, Hydrodynamic characteristics of different reactors: mechanically agitated contactors, bubble columns, slurry reactors, spray columns, loop reactors and modified versions; Design aspects of multiphase reactors: Determination of controlling step, determination of intrinsic kinetics and factors affecting intrinsic kinetics, pressure drop, fractional phase hold- up, mass and heat transfer coefficient, extent of mixing, etc.

Module III - Advanced Process Control

Modeling of a few complicated systems, State space and transfer function matrix models, Stability criterion of transfer function matrix models, Development of empirical model from process data, Identifying Discrete-Time models from experimental data, Mathematical analysis of automatic process control. Analysis and synthesis of linear and nonlinear feedback control systems. Introduction to computer aided control. Digital simulation and computation of control systems, Computer solutions to optimum control and control problems.

Module IV - Advanced Modeling, Simulation and Optimization

Multiscale simulations in materials, Industrial flow modeling, Data driven modeling, Non-linear system dynamics, modeling of chemical process optimization, advanced simulation approaches using CFD, etc. multi-variable and multi-objective optimization.

Module V - Artificial intelligence in Chemical Engineering

Artificial intelligence: Role in chemical engineering. Knowledge representation; Heuristic knowledge; Rule-based knowledge; Decision trees; object oriented programming. Artificial neural networks: Pattern recognition; Classification; Process optimization. Data mining: Windowing techniques; Wavelet transforms- noise, filtering, pattern recognition. Uncertainty: Fuzzy logic- definition; possibility theory; fuzzy numbers and fuzzy arithmetic; Genetic algorithm; Simulated annealing. Expert Systems: Knowledge based systems; Fuzzy expert systems; Buildingand expert systems Applications of AI in Chemical Processes.

Learning Resources

Text Books

1. Introduction to Chemical Engineering Thermodynamics, J.M. Smith, Van Ness H.C McGraw Hills, New York
2. Chemical Reaction Engineering, Octave Levenspiel, John Wiley and Sons, New York
3. Process systems Analysis &Control, Donald R. Coughanowr, McGraw Hill publications
4. Process Modeling, Simulation and Control for Chemical Engineers, Luyben, International Student Edition

Reference Books:

1. Thermodynamics and Its Applications, Jefferson W. Tester, Michael Modell Prentice Hall, India
2. Textbook of Chemical Engineering Thermodynamics, Narayanan, K.V Prentice Hall, India
3. Catalysis (Vols. I & II) Emmett, P.H. Reinhold Publishing Corporation, New York
4. Elements of Chemical Reaction Engineering, Fogler H.S Prentice Hall, New York
5. Chemical Engineering Kinetics, Smith J.M McGraw- Hill Book Company, New York
6. Chemical Reactor Design and Analysis, Bischoff and FromentAddision Wesley, New York
7. Richardson and Coulson- Chemical Engineering Vol. 1-6

8. Chemical Process Control, An Introduction to theory & Practice, George Stephenopoulos, Person education.
9. Modeling and Simulation in Chemical Engineering, Franks R.E. John Wiley
10. Optimization Techniques for Chemical Engineers, T.F. Edgar, D.M. Himmelblau McGraw-Hill
11. Optimization Techniques, K. Deo Wiley Eastern
12. Problem Solving Methods in Artificial Intelligence, by N L Nilsson
13. Artificial Intelligence in Chemical Engineering, T. E. Quantrille, Y. A. Liu
14. Introduction to Artificial Neural Systems, J. Zuarda
15. Intelligent Systems in Process Engineering, G Stephanopoulos, V. Venkatasubramanian

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
COM-SPC1 : Mathematics for Computer Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Prerequisite Courses :

1. Derivative, integration, matrices, solution of simultaneous equations, partial differentiation

Course Objectives: The course aims to:
To solve first order linear, non linear partial differential equations, second order partialdifferential equations, Solve differential equations using Laplace Transforms.

Course Outcomes: Upon successful completion of this course, students will be able to:

- CO 1:. Understand and apply concepts of partial differentiation relevant to engineering problems.
- CO 2: Employ numerical methods and matrix algebra techniques to perform computational analysis.
- CO 3: Apply probability theory and probability distributions to model uncertainty and randomness in computer engineering contexts.
- CO 4: Analyze relationships between variables using correlation and regression techniques to interpret data trends and dependencies.
- CO 5: Evaluate data sets using goodness of fit tests and variance analysis to assess model suitability and variability in experimental data.

Course Contents

Module I - Partial Differentiation

Partial Derivatives, Euler's Theorem on homogeneous and non-homogeneous functions, Total derivative, Chain rules, Jacobian, Errors and approximations, Maxima and minima of functions of two variables, Lagrange's methods of undetermined multipliers

Module II - Numerical Methods and Matrices

Numerical solutions of linear algebraic equations, Numerical solutions of differential equations by Euler's, and Runge Kutta fourth order method, Integration by trapezoidal and Simpson's rule. Definition of a matrix, types of matrices, Algebra of matrices, Inverse of a matrix by Adjoint method and by Elementary transformation, Rank of a matrix, Solution of system of Linear homogeneous and non-homogeneous equations, Eigen values, Eigen vectors, Cayley Hamilton theorem

Module III - Probability and Probability Distribution

Introduction and definition and of probability, probability and set notations, theorem of total probability, independent events, Bay's theorem, Random variables (discrete and continuous), discrete

probability distribution, continuous probability distribution, moments and expectations, generating function, repeated trials, probability distributions including Binomial, Poisson, Normal, probable error

Module IV - Correlation and Regression

Introduction of correlation, correlation analysis, coefficient of correlation, probable error, regression, regression analysis, line of regression, standard error of estimate, Rank of correlation. single and multiple regression, linear, non-linear regression

Module V - Goodness of fit and Variance

Concept and necessity of goodness of fit, K-S test for goodness of fit and distribution. Variance, co variance, analysis of variance on one way & two-way classification

Learning Resources

Text Books

1. Advanced Engineering Mathematics by Erwin Kreyszig (Wiley India).
2. Statistical Methods by S. P. Gupta, (S. Chand Publication, Delhi).

Reference Books:

1. Higher Engineering Mathematics by B. S. Grewal (Khanna Publication, Delhi).
2. Statistical Methods by Gupta S.P (43rd edition, S. Chand Publication)

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
COM-SPC2 - Advances in Computer Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Any THREE of the following topics or modules can be covered as part of the course.

Course Objectives : the course aims to:

1. Familiarize scholars with current research trends and emerging areas in Computer Engineering.
2. Deepen understanding of advanced computing architectures, algorithms, and intelligent systems.
3. Develop the ability to critically analyze research literature and identify potential research problems.
4. Enhance skills in experimental design, simulation, and result analysis for high-quality research.

Course Contents

Module I - Multi Core Architectures

- Multicore, Many-core, and Heterogeneous Architectures
- Quantum and Neuromorphic Computing Fundamentals
- Cloud–Edge–Fog Continuum: Architecture and Coordination
- Green and Energy-Efficient Computing
- Case Studies: NVIDIA CUDA, Google TPU, ARM Neoverse

Module II - Advanced Algorithms and Optimization

- Approximation and Randomized Algorithms
- Parallel and Distributed Algorithms
- Bio-inspired and Evolutionary Computation
- Metaheuristics (GA, PSO, ACO, DE, etc.)
- Algorithmic Complexity and Scalability

Module III - Intelligent Systems and Machine Learning

- Deep Learning Architectures (CNN, RNN, GNN, Transformers)

- Reinforcement Learning and Generative Models
- Explainable AI and Trustworthy AI
- Federated and Edge-based AI Systems
- Applications: Computer Vision, NLP, Cybersecurity

Module IV - Wireless Technology

- Design issues and System Architecture
- Sensor Network OS Tiny OS, Nes C Language,
- Distributed data processing, Synchronization and localization,
- Communication and routing, Security issues , services and applications Mobile Ad-hoc Networks
- Location Management Schemes, Routing. GSM and satellite Communication: Architecture, hand-off and power management.
- Wireless Network Standards & Protocols

Module V - Network Security

- Network threats and attacks, Security Services,
- Cryptographic algorithms,
- Network Security Protocols, System Security,
- Security research in wired, wireless and ubiquitous networks,
- Security Standards and RFCs

Module VI - Software Project Planning & Management

- The Metrics Roadmap, A Typical Metrics Strategy, Metrics in software configuration management,Metrics for the Estimation processes
- Design to standards, design for portability, user interface issues, design for testability, design for diagnose ability, design for maintainability,
- Globalization issues in project management: Evolution of globalization, challenges in building global teams,
- Software Design Patterns, Designing with Distributed Objects:

Module VII - Natural Language Processing and Language Translation

- Grammars and Parsing, Grammars for Natural Language,

- Ambiguity Resolution: Statistical Methods, Linking Syntax and Semantics
- Language Processing: applications and key issues; lexicon and morphology; Phrase structure grammars and English syntax
- Part of speech tagging; Syntactic parsing, top down and bottom-up parsing strategies; Semantics, Word Sense Disambiguation,
- Semantic parsing; Information retrieval and Question answering; knowledge representation and reasoning, local discourse context and reference

Module VIII - Emerging Technologies in Computer Engineering

- Internet of Things (IoT) and Cyber-Physical Systems
- Blockchain and Secure Distributed Ledgers
- 5G/6G Networks and Network Virtualization
- Human–Computer Interaction and Augmented Intelligence
- Quantum Communication and Cryptography

Module IX - Data Engineering and Cloud Intelligence

- Big Data Analytics and Real-Time Stream Processing
- Cloud-Native Technologies and Microservices
- Serverless Computing and Orchestration (Kubernetes, Docker)
- Data Governance, Privacy, and Federated Learning
- Knowledge Graphs and Semantic Computing

Module X - Cyber-Physical Systems and IoT

- Internet of Things (IoT) and Industrial IoT Architectures
- Cyber-Physical System Design Principles
- Embedded AI and Sensor Fusion
- Interoperability and Edge Security Challenges
- Real-Time Operating Systems (RTOS) and Scheduling for IoT

Text Books

1. Stuart Russel,Peter Norvig, “Artificial Intelligence – A Modern Approach”, Second Edition, PHI/Pearson Education

2. Ethem Alpaydin, “Introduction to Machine Learning”, PHI

3. Holger Kars,” Protocols and architectures for WSN” , Wiely publication

4. Robert Bragg, Mark Rhodes, “Network Security: The complete reference”, TMH

5. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein, “Introduction to Algorithms,” Third Edition PHI 2010.

6. Christopher D. Manning and Hinrich Schütze, “Foundations of Statistical Natural Language Processing”, MIT Press,1999.

7. Akshar Bharati, Vineet Chaitanya, Rajiv Sangal, “Natural Language Processing- A Paninian Perspective”, PHI

Reference Books:

1. Simon Hhaykin, “Neural networks - A comprehensive foundations”, Pearson Education 2nd Edition 2004

2. Tom Mitchell, “Machine Learning”, MGH

3. Patrick Henry Winston, “Artificial Intelligence”, 3rd Edition, Pearson Education.

4. M Jochen Schiller, “Mobile communication”, Person Publication.

5. Mathew Gast, “802.11 wireless Networks the definitive guide”, O’Reilly.

6. William Stallings, “Cryptography and Network Security”, Fourth Edition,Pearson Education 2007.

7. Behrouz A. Forouzan, “Cryptography & Network Security”, TMH 2007.

8. G Coulouris, J Dollimore and T Kindberg, “Distributed Systems Concepts and Design”, Third Edition, Pearson Education.

9. Kai Hwang, Faye A.Brigs, “Computer Architecture and Parallel Processing”, Mc Graw Hill

10. James Allen, “Natural Language Understanding”, Pearson Education, 2nd Edition

11. James Allen, “Natural Language Understanding”, Pearson Education, 2nd Edition 2.

12. Christopher D. Manning and Hinrich Schütze. 1999. Foundations of Statistical Natural Language Processing. MIT Press.

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
IN-SPC1: Mathematics for Instrumentation Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Prerequisite Courses :

1. Derivative, integration, matrices, solution of simultaneous equations, partial differentiation

Course Objectives: The course aims to:
To solve first order linear, non linear partial differential equations, second order partialdifferential equations, Solve differential equations using Laplace Transforms.

Course Outcomes: Upon successful completion of this course, students will be able to:

- CO1: Apply advanced linear algebra and matrix theory concepts such as eigen decomposition, factorizations, and matrix properties to solve problems in signal processing, MIMO systems, and coding theory.
- CO2: Analyze probability, random processes, and stochastic models to characterize noise, communication channels, and queuing systems using appropriate statistical methods.
- CO3: Utilize transform methods and functional analysis techniques, including Fourier, Laplace, Z, and wavelet transforms, for signal representation, spectral analysis, and filtering.
- CO4: Formulate and solve optimization problems using classical, convex, numerical, and heuristic methods, with applications in adaptive filtering, machine learning, and engineering design.
- CO5: Model, analyze, and interpret the behavior of dynamical systems using differential equations, stability theory, and chaos analysis, with applications in control and engineering systems.

Course Contents

Module I - Advanced Linear Algebra and Matrix Theory

Vector spaces, subspaces, bases, and dimension Eigen values, eigenvectors, and diagonalization Hermitian, Moduleary, and normal matrices Matrix factorizations (QR, SVD, Schur decomposition) Applications in signal processing, MIMO systems, coding theory.

Module II -Probability, Random Processes, and Stochastic Analysis

Probability spaces, conditional probability, Bayes' theorem Random variables and distributions (Gaussian, Poisson, Rayleigh, etc.) Expectation, variance, correlation, covariance Random processes: stationary, periodicity, power spectral density Markov chains and Markov processes Stochastic calculus and Wiener process basics Applications in communication channels, noise analysis, queuing models

Module III- Transform Methods and Functional Analysis

Fourier series and Fourier transform Laplace transform, Z-transform, Hilbert transform Wavelet transform and time-frequency analysis Distributions and generalized functions (Dirac delta, impulse functions) Normed linear spaces, Hilbert and Banach spaces Applications in signal representation, filtering, spectral analysis

Module IV Optimization Techniques

Classical optimization (unconstrained and constrained) Convex sets and convex optimization Lagrange multipliers, Kuhn-Tucker conditions Numerical optimization: gradient descent, Newton's method, quasi-Newton methods Evolutionary and heuristic optimization (genetic algorithms, PSO) Applications in adaptive filtering, machine learning, antenna design

Module V Differential Equations and Dynamical Systems

Ordinary differential equations (ODEs): linear and nonlinear Partial differential equations (PDEs): wave, heat, diffusion, and Laplace equations, Stability analysis: Lyapunov stability, bifurcation theory Dynamical systems and chaos theory Applications in control systems

Learning Resources

Reference Books:

1. Papoulis & Pillai – Probability, Random Variables and Stochastic Processes
2. Stark & Woods – Probability and Random Processes with Applications to Signal Processing
3. Kreyszig – Advanced Engineering Mathematics
4. Boyd & Vandenberghe – Convex Optimization
5. Oppenheim & Schafer – Discrete-Time Signal Processing
6. Strang – Linear Algebra and Its Applications
7. Haykin – Communication Systems

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
IN-SPC2: Advances in Instrumentation Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Any THREE of the following topics or modules can be covered as part of the course.

Course Outcomes: Upon successful completion of this course, students will be able to:

- CO1: Understand the fundamentals, characteristics, and classifications of modern sensors, transducers, control systems, and safety instrumentation used in industrial and biomedical applications.
- CO2: Apply advanced control strategies, intelligent control techniques, and signal/image processing methods to analyze, model, and solve real-world engineering problems.
- CO3: Design and evaluate safety instrumented systems (SIS), human–machine interfaces (HMI), and machine vision systems for automation, robotics, and process industries.
- CO4: Analyze biomedical instruments, biosignals, and medical imaging systems for healthcare applications with emphasis on diagnosis, monitoring, and patient safety.
- CO5: Explore emerging technologies such as MEMS, IoT-based smart sensors, nanotechnology, and AI-driven intelligent systems for innovations in industry, agriculture, medicine, and advanced research.

Course Contents

Module I- Advance in Sensors and Transducers

Fundamentals, characteristics, and classifications of modern sensors/transducers along with advanced technologies like MEMS, smart, bio, and IoT-based sensors. Signal conditioning, interfacing, and emerging applications in industry, agriculture, healthcare, robotics, and automation.

Module II- Advance Control System

State-space analysis, controllability, observability, and stability, modern control design techniques like pole placement and optimal control. Nonlinear, adaptive, and digital control strategies with applications in engineering systems.

Module III- Safety Instrumentation

Principles of safety systems, hazard identification, risk analysis, and safety integrity levels (SIL). Design, implementation, and maintenance of safety instrumented systems (SIS) for industrial process safety and automation.

Module IV - Intelligent Control

Control techniques based on artificial intelligence such as fuzzy logic, neural networks, and evolutionary algorithms. It emphasizes adaptive, learning-based, and hybrid control strategies for complex and nonlinear systems.

Module V- Signal and Image Processing

Fundamentals of discrete-time signals, transforms, filtering, sampling, and reconstruction. Image enhancement, restoration, compression, segmentation, and feature extraction for real-world applications.

Module VI- Machine Vision

Image acquisition, preprocessing, segmentation, feature extraction, and object recognition. 3D vision, pattern recognition, and applications in automation, robotics, and quality inspection.

Module VII-Human Machine Interface

Principles of user interface design, ergonomics, and interaction methods between humans and machines. HMI hardware/software, visualization, control panels, and applications in automation and process industries.

Module VIII- Biomedical Instrumentation

Principles, design, and working of medical instruments for measuring physiological parameters such as ECG, EEG, blood pressure, and respiration. Bio-signal acquisition, processing, imaging systems, and applications in diagnosis and healthcare.

Module IX- Nano Technology

Fundamentals of nonmaterial's, their synthesis, characterization, and unique properties at the nanoscale. Applications in electronics, energy, medicine, and emerging nanodevices for advanced technologies.

Learning Resources

Reference Books:

1. D. Patranabis, Sensors and Transducers, PHI Learning.
2. John G. Webster, Measurement, Instrumentation, and Sensors Handbook, CRC Press.
3. S.C. Bhargava, S. Chand Transducers and Instrumentation,.
4. Katsuhiko Ogata, Modern Control Engineering, Prentice Hall.
5. Richard C. Dorf & Robert H. Bishop, Modern Control Systems, Pearson.
6. Gene F. Franklin, J. Powell, & A. Emami-Naeini, Feedback Control of Dynamic Systems, Pearson.
7. Paul Gruhn & Harry L. Cheddie, Safety Instrumented Systems: Design, Analysis, and Justification, ISA.
8. William M. Goble & Harry Cheddie, Safety Instrumented System Verification, ISA.
9. David Macdonald, Practical Industrial Safety, Risk Assessment and Shutdown Systems, Elsevier
10. K. M. Passino & S. Yurkovich, Fuzzy Control, Addison-Wesley.
11. Danilo P. Mandic & Jonathon A. Chambers, Recurrent Neural Networks for Prediction, Wiley.

12. R. J. Howlett, Intelligent Control: Emerging Techniques and Applications, CRC Press.

13. Charles P. Poole & Frank J. Owens, Introduction to Nanotechnology, Wiley.

14. T. Pradeep, A Textbook of Nanoscience and Nanotechnology, Tata McGraw-Hill.

15. B. S. Murty et al., Textbook of Nanoscience and Nanotechnology, Springer.

16. Alan V. Oppenheim & Ronald W. Schafer, Discrete-Time Signal Processing, Pearson.

17. Rafael C. Gonzalez & Richard E. Woods, Digital Image Processing, Pearson.

18. Simon Haykin & Barry Van Veen, Signals and Systems, Wiley.

19. Ramesh Jain, Rangachar Kasturi & Brian G. Schunck, Machine Vision, McGraw-Hill.

20. E. R. Davies, Computer and Machine Vision: Theory, Algorithms, Practicalities, Academic Press.

21. Milan Sonka, Vaclav Hlavac & Roger Boyle, Image Processing, Analysis, and Machine Vision, Cengage.

22. Jenifer Tidwell, *Designing Interfaces, O'Reilly.

23. Ben Shneiderman et al., Designing the User Interface: Strategies for Effective Human-Computer Interaction, Pearson.

24. Alan Dix et al., Human-Computer Interaction, Pearson.

25. R.S. Khandpur, Handbook of Biomedical Instrumentation, McGraw-Hill

26. John G. Webster, Medical Instrumentation: Application and Design, Wiley

27. Richard Aston, *Principles of Biomedical Instrumentation and Measurement, Macmillan.

28. Rangaraj M. Rangayyan, Biomedical Signal Analysis: A Case-Study Approach, Wiley-IEEE Press

29. Willis J. Tompkins, Biomedical Digital Signal Processing: C-based Examples, Prentice Hall

30. Rangaraj M. Rangayyan, Biomedical Image Analysis, CRC Press

31. Atam P. Dhawan, Medical Image Analysis, Wiley-IEEE Press

32. Jayaraman, Esakkirajan & Veerakumar, Digital Image Processing, Tata McGraw-Hill (with biomedical applications).

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
PEE-SPC1 – Mathematics for Production and Industrial Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Course Objectives: The course aims to:

The course aims to equip students with mathematical tools in linear algebra, mathematical modelling and optimization, probability etc. to analyse, model and optimize the manufacturing processes and production systems.

Course Contents

Module I - Matrices

Definitions of various types of matrices, Eigen value and Eigen vectors, Applications of matrices for finite element methods, Rank of matrix, system of linear equation, Linear Dependent and Indecent, Linear and Orthogonal Transformation.

Module II -Probability, Random Processes, and Stochastic Analysis

Probability spaces, conditional probability, Bayes' theorem Random variables and distributions (Gaussian, Poisson, Rayleigh, etc.) Expectation, variance, and correlation, covariance Random processes: stationarity, ergodicity, power spectral density Markov chains and Markov processes stochastic calculus, applications in statistical quality control, inventory models, queuing models etc.

Module III- Correlation and Regression

Introduction of correlation, correlation analysis, coefficient of correlation, probable error, regression, regression analysis, line of regression, standard error of estimate, Rank of correlation. single and multiple regression, linear, non-linear regression

Module IV Differential Equations and application

Linear Differential Equation: nth order with constant coefficients, complementary function, Particular Integral, General Method, Method of variation of parameter. Partial Differential Equation: Parabolic and Hyperbolic system, 1-d and 2-d solution method, stability analysis, PDE application in optimization

Module V - Optimization and Mathematical Modelling

Classical optimization (unconstrained and constrained) Convex sets and convex optimization Lagrange multipliers, Kuhn-Tucker conditions Numerical optimization: gradient descent, Newton's method, quasi-Newton methods Evolutionary and heuristic optimization (genetic algorithms, PSO), Mathematical modelling and multi-objective optimization of manufacturing processes and production systems.

Learning Resources

Reference Books:

1. Trivedi, K. S., Probability and Statistics with Reliability, Queuing, and Computer Science Applications. John Wiley & Sons, Inc.

2. Kreyszig, Erwin. Advanced Engineering Mathematics, John Wiley & Sons, Inc.

3. V. P. Mikhailov, Partial Differential Equations, Manakin Press

4. Peter O'Neil, Advanced Engineering Mathematics, Cengage Learning,

5. S. S. Rao, Engineering Optimization: Theory and Practice, Wiley, 4th Edition.

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
PEE-SPC2: Advances in Production and Industrial Engineering		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 4 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Any THREE of the following topics or modules can be covered as part of the course.

Course Objectives:

- To familiarize the students with latest concepts and techniques in Production and Industrial Engineering.
- These concepts will help the students to know the latest trends in Production and Industrial engineering which will help them in identifying the topic of research and further completion of their research work.

Course Contents - Advanced Materials Engineering

Module I- Nano materials and Nano-Composites

Synthesis of Nanomaterials: Top down approaches and bottom down approaches, carbon based Nano materials, synthesis and properties, applications, metallic and ceramic Nano materials: catalytic and bio medical applications, Nano composites,

Module II- Smart and Functional materials

Characteristics of smart materials, Stimuli and response mechanisms, Piezoelectric Materials: Constitutive equations, Lead zirconated titanate (PZT), Sensors and actuators, Piezo-electric energy harvesting, Shape Memory Materials: Shape Memory Alloys (SMA) – phase transformation, Nitinol properties, Applications in robotics and biomedical devices, Magneto-strictive Materials, Smart Fluids: ER & MR fluids

Module III- Computational Materials Science

Linear algebra and tensor mathematics, Differential equations in materials science, Atomistic Modelling, Molecular dynamics (MD), Monte Carlo simulations, Applications in diffusion, phase transitions, Quantum Mechanical Methods: Schrödinger equation, Density Functional Theory (DFT), Thermodynamics and Phase Modelling, Microstructure Modelling, Multiscale Modelling, Computational Tools and Software

Module IV - Advanced Material Characterisation Techniques

X-Ray Based Techniques, X-ray Diffraction (XRD): phase identification, crystallite size, residual stress, X-ray fluorescence (XRF), Electron Microscopy: Scanning Electron Microscopy, Transmission Electron Microscopy (TEM), Energy dispersive spectroscopy (EDS/EDX), Electron backscatter diffraction (EBSD), Scanning Probe Microscopy: Atomic Force Microscopy (AFM), Thermal Analysis Techniques, Mechanical Characterisation at Micro/Nano Scale

Learning Resources

Reference Books:

1. Cao, G., & Wang, Y., Nanostructures and Nanomaterials: Synthesis, Properties and Applications, World Scientific Publishing, Singapore.
2. Edelstein, A. S., & Cammarata, R. C., Nanomaterials: Synthesis, Properties and Applications. Institute of Physics Publishing, UK.
3. M. V. Gandhi and B. S. Thompson, Smart materials and structures. Chapman and Hall, London.
4. Richard LeSar, Introduction to Computational Materials Science: Fundamentals to Applications, Cambridge University Press.
5. June Gunn Lee, Computational Materials Science: An Introduction, Taylor and Francis.
6. Yang Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Wiley

Course Contents - Advanced manufacturing Processes

Module I- Mechanical and Thermal Energy Based Processes

Abrasive Water Jet Machining (AWJM), Ultrasonic Machining (USM), Process parameters and applications, Laser Beam Machining (LBM), Electron Beam Machining (EBM), Plasma Arc Machining (PAM), Ion Beam Machining (IBM), Heat affected zone (HAZ) analysis

Module II- Electrical Energy Based Processes

Electrical Discharge Machining (EDM), Wire EDM, Die-sinking EDM, Electro-Discharge Grinding (EDG) Electro-Discharge Grinding (EDG), Surface integrity and tool wear, Process parameter optimization and applications

Module III- Chemical and Electrochemical Processes

Chemical Machining (CHM), Photochemical Machining (PCM), Electrochemical Machining (ECM), Electrochemical Grinding (ECG), Fundamentals of electrolysis, Process modelling and parameter optimization

Module IV - Recent trends in Manufacturing Processes

Additive manufacturing, Digital Twin and Virtual Manufacturing, Precision and Nano-Manufacturing, Robotics and Automation, Sustainable and Green manufacturing, Energy Optimization in Manufacturing

Learning Resources

Reference Books:

1. P. K. Mishra, Non-Traditional Machining (3rd Edition), Narosa Publishing House
2. Hassan Abdel-Gawad El-Hofy, Advanced Machining Processes: Non-traditional and Hybrid Machining Processes, McGraw Hill Professional

3. Amit Bandyopadhyay, Susmita Bose, Additive Manufacturing, CRC Press

4. David A. Dornfeld (Editor), Green Manufacturing: Fundamentals and Applications, Springer Science & Business Media

Course Contents - Manufacturing systems and Automation

Module I- Flexible Manufacturing Systems

FMS Layout and Configuration, Group Technology and Cellular Manufacturing, Computer Control in FMS, Manufacturing Execution Systems (MES), FMS Planning and Design, FMS Scheduling and Control, Performance Analysis of FMS, Simulation and Modelling of FMS.

Module II- Cyber Physical Systems

Smart Manufacturing and Industry 4.0, IOT based systems, Sensors, Actuators and Data Acquisition, Industrial Communication and Networking, Embedded Systems and Controllers, Modelling and Control of Cyber Physical Systems, Cybersecurity in Manufacturing, Cyber Physical Systems for Additive and Advanced Manufacturing, Standards and Interoperability

Module III- Autonomous Production Systems

Autonomous Robotics in Production: Industrial robots, Collaborative robots, adaptive motion planning and obstacle avoidance, Self-calibration and learning robots , Autonomous Material Handling Systems: AGVs and AMRs, Palletising, Automated storage and retrieval systems, Autonomous Decision-Making Systems: Multi-agent systems, Self-optimization techniques, Real-time scheduling algorithms, Autonomous resource allocation, Autonomous Quality Control: Machine vision inspection, AI-based defect detection, Self-correcting production systems

Module IV - Computational Methods and Simulation

Optimization Techniques: Linear and non-linear programming, Integer and mixed integer programming, dynamic programming, goal programing, metaheuristics, Simulation Modelling Techniques: Discrete event simulation, Continuous simulation, Monte Carlo simulation, System dynamics modelling, Finite Element Method (FEM) in Manufacturing, Modelling of Manufacturing Processes, Production Planning and Scheduling Simulation, Software Tools for Simulation

Learning Resources

Reference Books:

1. H. K. Shivanand, Flexible Manufacturing System, New Age International

2. Raj Rajkumar, Dionisio de Niz, Mark Klein, Cyber-Physical Systems, Addison-Wesley Professional.

3. Automation, Production Systems, and Computer-Integrated Manufacturing, Mikell P. Groover, Prentice Hall Press

4. W. Fred Ramirez, Computational Methods for Process Simulation, Butterworth-Heinemann

Course Contents - Advance in Industrial Engineering

Module I- Supply Chain management

Supply chain network design, Inventory optimization models, Bullwhip effect and mitigation, Resilient and sustainable supply chains, Digital supply chain systems, Supply chain software, performance evaluation, case studies.

Module II- Human Factor Engineering

Advanced ergonomic analysis, Human–machine interaction, Work system design, Occupational safety and risk assessment, Cognitive ergonomics

Module III- Reliability Engineering and Maintenance Management

Reliability modelling, Failure analysis techniques, Preventive and predictive maintenance, Condition monitoring, Total productive maintenance (TPM)

Module IV - Sustainable and Green Industrial Systems

Sustainable manufacturing, Life cycle assessment (LCA), Carbon footprint analysis, Circular economy concepts, Energy-efficient systems

Learning Resources

Reference Books:

1. Piyush Shah and Elias (Lee) Kirche, Supply Chain Management – An Integrated Approach
2. Ailawadi, Satish C., Singh, P. Rakesh, Logistics and Supply Chain Management, PHI Learning.
3. Ernest J. McCormick (Author), Mark S. Sanders, Human Factors in Engineering and Design, McGraw-Hill Inc., US
4. R.T. Anderson, L. Neri, Reliability-Cantered Maintenance: Management and Engineering Methods, Springer
5. Thomas E Graedel and Matthew J Eckelman, Industrial Ecology and Sustainability, World Scientific Publishing

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
PPT – SPC1 – Mathematics for Printing & Packaging Technology		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Course Objectives:

1. Apply numerical approximation techniques.
2. Utilize numerical integration and differential equations to model packaging systems.
3. Analyze and interpret statistical measures.
4. Develop predictive models using regression and correlation analysis.
5. Apply probability distributions and statistical quality control concepts.

Course Contents

Module I - Numerical Approximation & Interpolation in Printing

Finite Difference Applications: Utilizing forward and backward formulas to calculate gradients in ink-film thickness and solvent evaporation rates. Heat Transfer Modeling: Applying numerical derivatives to simulate the thermal curing and drying of coatings on diverse substrates., Lagrange's Interpolation: Reconstructing continuous spectral reflectance curves and spectrophotometric data from discrete measurements, Substrate Characterization: Modeling the non-linear stress-strain behavior of polymers and sustainable foils using polynomial interpolation.

Module II - Computational Integration & Differential Analysis in Packaging

Numerical Integration Techniques: Employing Simpson's and Trapezoidal rules to determine the total energy absorption during package drop tests, Volumetric Analysis: Calculating the precise volume and material distribution of complex, non-uniform 3D packaging geometries, Ordinary Differential Expressions: Modeling the kinetics of gas permeation through barrier films to predict product shelf-life, Dynamic Simulation: Solving ODEs via numerical methods (e.g., Runge-Kutta) to analyze vibration damping and mechanical failure during the distribution cycle.

Module III - Descriptive Analytics & Precision Metrics

Root Mean Square (RMS): Application in quantifying surface topography of paper and polymers; analyzing noise in digital imaging sensors. The Method of Moments: * First Moment (Mean): Central tendency of ink film thickness. Second Moment (Variance): Consistency in color reproduction Third & Fourth Moments (Skewness & Kurtosis): Analyzing the "tail" of defect distributions in high-volume production. Practical Lab: Using RMS to evaluate the printability of recycled vs. virgin fiber boards.

Module IV - Relational Modeling & Print Quality

Correlation Analysis, Simple & Multiple Linear Regression: Developing predictive models, Coefficient of Correlation and Determination, Quantifying how much of a printing defect is actually explained by machine vibration versus material inconsistency.

Module 5: Probability Models for Quality & Reliability

Binomial Distribution: Modeling "Pass/Fail" scenarios in discrete sampling, Poisson Distribution, Normal (Gaussian) Distribution: The Foundation of Six Sigma, Central Limit Theorem: Understanding a bell curve, advanced Application: Using Normal distribution to set "Upper and Lower Control Limits" (UCL/LCL) for automated inspection systems.

Learning Resources

Text Books:

1. S. C. Chapra and R. P. Canale, Numerical Methods for Engineers, 7th ed. New York, NY, USA: McGraw-Hill, 2015.
2. B. S. Grewal, Higher Engineering Mathematics, 44th ed. New Delhi, India: Khanna Publishers, 2018.
3. R. K. Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, 5th ed. New Delhi, India: Narosa Publishing House, 2016.
4. D. C. Montgomery and G. C. Runger, Applied Statistics and Probability for Engineers, 7th ed. Hoboken, NJ, USA: Wiley, 2018.
5. J. S. Bendat and A. G. Piersol, Random Data: Analysis and Measurement Procedures, 4th ed. Hoboken, NJ, USA: Wiley, 2010.

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
PPT – SPC1 – Advances in Printing & Packaging Technology		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week	04	**CCE** : 50 Marks **End-Semester**: 50 Marks

Any THREE of the following topics or modules can be covered as part of the course.

Course Objectives: The course aims to:

1. Enable scholars to critically analyze and innovate in advanced printing technologies, packaging materials, and production systems.
2. Equip students with the ability to design, conduct, and publish high-quality research addressing emerging challenges in printing and packaging.
3. Foster the development of eco-friendly, circular, and resource-efficient printing and packaging solutions.
4. Encourage integration of material science, digital technologies, automation, and design thinking in solving complex industry problems.
5. Prepare scholars to develop solutions that improve product safety, user experience, supply chain efficiency, and regulatory compliance.

Course Contents

Module I - Advanced Print Technologies

Advanced offset, flexography, gravure, and digital printing innovations, including hybrid systems and nanographic printing.

Module II - Functional Printing & Printed Electronics

Study of printed sensors, RFID, flexible circuits, OLEDs, and applications in smart packaging.

Module III - Packaging Materials Science

Advanced properties of polymers, paperboard, bioplastics, nanocomposites, and barrier materials and biopolymer coatings

Module IV - Sustainable & Circular Packaging Systems

Life cycle assessment (LCA), recyclability, biodegradable materials, and circular economy models

Module V - Color Science & Advanced Color Management

Spectral imaging, ICC profiling, color reproduction models, and AI-driven color correction

Module VI - Print Quality Engineering & Process Control

Statistical quality control, machine vision systems, defect detection, AI enabled fault detection and process optimization.

Module VII - Smart & Intelligent Packaging

Active packaging, IoT-enabled packaging, time-temperature indicators, and interactive labels.

Module VIII -Ink Chemistry & Coating Technologies

Formulation of inks (UV, water-based, solvent-based), rheology, drying kinetics, and surface coatings.

Module IX - Automation, AI & Industry 4.0 in Printing

Machine learning, predictive maintenance, robotics, and workflow automation in print production.

Module X - Advanced Prepress & Digital Workflow Systems

PDF standards, color workflows, RIP technologies, and cloud-based print management.

Module XI - Packaging Design Engineering & Prototyping

Structural design, CAD tools, ergonomics, usability testing, and rapid prototyping.

Module XII - Regulatory Affairs & Packaging Compliance

Global regulations (FDA, EU), labeling laws, food safety standards, and environmental compliance.

Module XIII - Supply Chain & Logistics for Packaging Systems

Optimization of packaging for transportation, warehousing, and e-commerce ecosystems.

Module XIII - Security Printing & Anti-Counterfeiting Technologies

Holography, forensic markers, blockchain in packaging, and authentication systems.

Module XIV - Human Factors & User Experience in Packaging

Focus on how users interact with packaging, including ergonomics, accessibility, cognitive perception, and behavioral responses. Covers usability testing, eye-tracking studies, inclusive design, and the role of packaging in consumer decision-making and brand communication.

Learning Resources

Reference Books:

1. J. Wang, Y. Wang, and L. Chen, Eds., Advances in Printing, Packaging and Communication Technologies. Singapore: Springer, 2023.
2. Y. Liu, Q. Zhao, and X. Zhang, Eds., Innovative Technologies for Printing and Packaging. Singapore: Springer, 2022.
3. Z. Wang, Ed., Advanced Graphic Communication, Printing and Packaging Technology. Singapore: Springer, 2020.
4. X. Chen and Y. Liu, Eds., Advances in Graphic Communication, Printing and Packaging Technology and Materials. Singapore: Springer, 2021.
5. J. Wu, Ed., Advanced Graphic Communications, Packaging Technology and Materials. Singapore: Springer, 2017.

6. H. Zhao and L. Shen, Eds., Advanced Printing and Packaging Materials and Technologies. Zurich, Switzerland: Trans Tech Publications, 2016.

7. T. Wang, Ed., Advances in Printing and Packaging Technologies. Zurich, Switzerland: Trans Tech Publications, 2014.

8. H. Kipphan, Ed., Handbook of Print Media: Technologies and Production Methods. Berlin, Germany: Springer, 2001.

9. A. Emblem and H. Emblem, Packaging Technology: Fundamentals, Materials and Processes. Cambridge, U.K.: Woodhead Publishing, 2012.

10. M. J. Kirwan, Paper and Paperboard Packaging Technology. Oxford, U.K.: Wiley-Blackwell, 2013.

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
RPE103 - Research and Publication Ethics		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 30 Hours	02	**CCE** : 15 Marks **End-Semester**: 35 Marks

Course Outcomes: Upon successful completion of this course, students will be able to:

- To gain insight into the ethical considerations involved in research and publication.
- To foster a strong sense of research integrity among scholars.
- To recognize and address research misconduct and identify predatory publications.
- To become familiar with indexing and citation databases, open access publications, and research metrics such as citations, h-index, and impact factor.
- To understand the use of plagiarism detection tools.

Course Contents

Module I: Introduction to Research Ethics and Integrity

Definition and importance of research ethics Historical context and key milestones in research ethics Definition and importance of research integrity
Truthfulness and accuracy in data collection, analysis, and reporting
The role of reproducibility and transparency

Module II: Research Misconduct

Definitions and examples of research misconduct (fabrication, falsification, plagiarism - redundant publications, duplicate and overlapping publications etc.)
Consequences of misconduct for researchers and the scientific commModuley Procedures for reporting and addressing misconduct

Module III: Authorship and Publication Ethics

Criteria for authorship and contributors Responsibilities of authors, reviewers, and editors Handling conflicts of interest and disclosures

Module IV: Predatory Publishing and Misleading Journals

Characteristics of predatory journals and publishers
How to identify and avoid predatory practices
Strategies for ensuring publication in reputable journals

Module V: Indexing and Citation Databases

Overview of indexing databases (e.g., PubMed, Scopus, Web of Science)
Citation metrics and their role (e.g., impact factor of journal as per Journal Citations Report, SNIP, SJR, IPP, Cite Score - Metrics: h-index, g index, i10 Index, altmetrics) Understanding open access and its impact on research dissemination

Module VI: Plagiarism and its Detection

Definitions and types of plagiarism

Tools and techniques for detecting plagiarism Strategies for avoiding plagiarism and ensuring originality

Module VII: Regulations and Guidelines

Overview of relevant regulations and guidelines (e.g., Belmont Report, Declaration of Helsinki)

Institutional policies and procedures

International standards and agreements

Learning Resources

Text Books

1. Nicholas H. Steneck. Introduction to the Responsible Conduct of Research. Office of Research Integrity. 2007. Available at: https://ori.hhs.gov/sites/default/files/rcrintro.pdf
2. Office of Research Integrity. "Introduction to the Responsible Conduct of Research." U.S. Department of Health and Human Services, 2007, ori.hhs.gov/education/products/RCRintro/.
3. Oliver, Paul. The Student's Guide to Research Ethics. Open University Press, 2003
4. Shamoo, Adil E & Resnik David B. Responsible Conduct of Research. Oxford University Press: London 2003
5. Kambadur, Muralidhar, Ghosh, Amit, and Singhvi, Ashok Kumar. Ed. Ethics in Science Education, Research and Governance Indian National Science Academy, 2019.
6. Anderson B.H., Dursaton, and Poole M.: Thesis and assignment writing, Wiley Eastern. 1997.
7. Gustavii, Bijorn: How to write and illustrate scientific papers? Cambridge University Press.
8. Bordens K.S. and Abbott, B.b.: Research Design and Methods, Mc Graw Hill, 2008.
9. Graziano, A., M., and Raulin, M.,L.: Research Methods – A Process of Inquiry, Sixth Edition, Pearson, 2007.
10. Resnik, David B. The Ethics of Science: An Introduction. Routledge, 1998.

Savitribai Phule Pune University **PhD Course Work (Engineering)**		
PIA104 - Pedagogical Training /Industrial Visit Report/Assessment Statement		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 30 Hours	01	**CCE** : 25 Marks

Nature of the Course : The nature of the course will be in the form of report preparation on the basis of industrial/field visits or participation in pedagogical training programmes.

Course Objectives: The course aims to:

- To enable the students to undertake focused background reading
- To enable them to use various tools and materials for research
- To enable them to make effective presentations

Pattern of Evaluation:

The students will have to complete any one of the following assignments. Submission of the assignment will carry 25 marks of the course.

1. A study report on an industrial/Field visit to the research organization where the experimental work is being carried out, other than your research center.
   (a) Places of Data set creation or collection or pedagogical training programmes
   (b) CSIR Research labs for experimental work
2. Participation in pedagogical training programmes of one week in the domain of the research.

Acknowledgment

Team Members for Course work Design

Name of the Faculty	Board of Studies
Dr. Sachin Sakhare	Computer Engineering
Dr. A. N. Sarwade	Electrical Engineering
Dr. S. S. Khule	Electrical Engineering
Dr. M. S. Thakare	Electrical Engineering
Dr. A. R. Laware	Electrical Engineering
Dr. Y. P. Reddy	Mechanical Engineering
Dr. Y. Ravinder	E & TC
Dr. Madhura Mahajan	Printing and Packaging Technology
Dr. P. S. Vikhe	Instrumentation Engineering

Chairmen of Board of Studies

Name of the Chairman	Board of Studies
Dr. Sunil Thakare	Civil Engineering
Dr. Suresh Shirbahadurkar	E&TC
Dr. Sanjay Deokar	Electrical Engineering
Dr. Pradeep Patil	Mechanical Engineering
Dr. Nilesh Uke	Computer Engineering
Dr. Sudeep Thepade	Information Technology
Dr. Keshav Nandurkar	Production and Industrial Engineering
Dr. Somnath Nandi	Chemical and Petroleum Engineering
Dr. Bhoomkar Manmohan	Printing Technology
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