# Amrita School of Computing
# Amrita Vishwa Vidyapeetham

## M.TECH DATA SCIENCE
## CURRICULUM 2026

## GENERAL INFORMATION

**Course Outcomes (CO)** – Statements that describe what students are expected to know, and are able to do at the end of each course. These relate to the skills, knowledge, and behaviour that students acquire in their progress through the course.

**Program Outcomes (POs)** – Program Outcomes are statements that describe what students are expected to know and be able to do upon graduating from the Program. These relate to the skills, knowledge, attitude, and behaviour that students acquire through the program. Program outcomes should be consistent with graduate attributes prescribed by NBA.

**Graduate Attributes prescribed by NBA for M-Tech Program**

GA1: Scholarship of knowledge

GA2: Critical thinking

GA3: Problem solving

GA4: Research skill

GA5: Usage of modern tools

GA6: Collaborative and multidisciplinary work

GA7: Project management and finance

GA8: Communication

GA9: Lifelong learning

GA10: Ethical practices and social responsibility

GA11: Independent and reflective learning.

## Scope

This program aims at preparing students in data science especially in data driven modeling and scientific computation. This program is tuned to cater to the demands in terms of skills required for the emerging scenarios in the industry and academia. Students will be skilled in domains such as Automation, Deep Learning, Multimodal Data Analysis, Generative AI and System Building.

## Program Outcomes

Graduates of this program will be able to

**PO1:** Develop an in depth understanding about the principles, tools and techniques pertinent to data science (GA1)

**PO2:** Apply the principles of data science to solve real life problems in various fields of Engineering, Physical and Natural Sciences. (GA2 & GA3)

**PO3:** Implement state of the art data analysis techniques in different computing platforms (GA5)

**PO4:** Arrive at innovative solutions for problems pertinent to data analysis in multiple domains (GA4 & GA6)

**PO5:** Able to identify and execute projects relevant to data analysis that will benefit the society (GA7, GA9, GA10 & GA11)

**PO6:** Able to communicate the findings of their analysis to scientific community through quality publications (GA4, GA9 & GA11)

## Program Specific Objectives (PSOs)

Graduates of the program will be able to

**PSO1**: Apply the mathematical concepts and techniques of data science to formulate solutions of real-world problems in industry relevant domains

**PSO2**: Design, implement, and evaluate data science algorithms and solutions to solve real-world problems while ensuring ethical practices, transparency, explainability, interpretability, fairness, and responsible use of data and AI systems.

**PSO3**: Conduct ethical research in data science and pursue a career in research and development pertinent to data science.

**SEMESTER I**

| Category | Course Code | Title | L-T-P | Credit |
|---|---|---|---|---|
| FC | 26MA603 | Computational Mathematics for Data Science | 3 0 3 | 4 |

| | | | | |
|---|---|---|---|---|
| FC | 26DS601 | Machine Learning | 3 0 3 | 4 |
| FC | 26DS602 | Foundation of Data Management | 3 0 3 | 4 |
| FC | 26RM605 | Research Methodology | 2 0 0 | 2 |
| SC | | SC-1 | 2 0 3 | 3 |
| SC | 25AVP501 | Mastery Over Mind (MA-OM) | 1 0 2 | 2 |
| HU | | Amrita Values Program | | P/F |
| HU | 26CDS601 | Career Development Skills I | 0 0 3 | P/F |
| | | **Total** | **30** | **19** |

**SEMESTER II**

| **Category** | **Course Code** | **Title** | **L-T-P** | **Credit** |
|---|---|---|---|---|
| FC | 26DS611 | Deep Learning | 3 0 3 | 4 |
| SC | | SC-2 | 2 0 3 | 3 |
| SC | | SC-3 | 2 0 3 | 3 |
| SC | | SC-4 | 2 0 3 | 3 |
| E | | Elective 1 | 2 0 3 | 3 |
| E | | Elective 2 | 2 0 3 | 3 |
| HU | 26CDS611 | Career Development Skills II | 0 0 3 | 1 |
| HU | 26CUL500 | IAM (Integrated Amrita Meditation) Technique | 0 0 2 | 1 |
| | | **Total** | **35** | **22** |

**SEMESTER III**

| **Category** | **Course Code** | **Title** | **L-T-P** | **Credit** |
|---|---|---|---|---|
| E | | Elective 3 | 2 0 3 | 3 |
| E | | Elective 4 | 2 0 3 | 3 |
| P | 26DS798 | Dissertation-I | | 11 |
| | | **Total** | **21** | **17** |

**SEMESTER IV**

| **Category** | **Course Code** | **Title** | **L-T-P** | **Credit** |
|---|---|---|---|---|
| P | 26DS799 | Dissertation-II | | 16 |
| | | Total | 16 | 16 |
| | | **Grand Total** | | **74** |

**LIST OF COURSES**

**FOUNDATION CORE**

| Course Code | Title | L-T-P | Credit |
|---|---|---|---|
| 26MA602 | Computational Mathematics for Data Science | 3 0 3 | 4 |

| | | | |
|---|---|---|---|
| 26DS602 | Foundation of Data Management | 3 0 3 | 4 |
| 26DS601 | Machine Learning | 3 0 3 | 4 |
| 26DS611 | Deep Learning | 3 0 3 | 4 |
| 26RM605 | Research Methodology | 2 0 0 | 2 |

**SOFT CORE**

| **Course Code** | **Title** | **L-T-P** | **Credit** |
|---|---|---|---|
| 26DS631 | Embedded Computing & Realtime OS for Data Science Applications | 2 0 3 | 3 |
| 26DS632 | Introduction to Statistical Modeling and Probabilistic Graphical Models | 2 0 3 | 3 |
| 26DS633 | Scientific Computing | 2 0 3 | 3 |
| 26DS634 | Text Mining and Analytics | 2 0 3 | 3 |
| 26DS635 | Big Data Framework for Data Science | 2 0 3 | 3 |
| 26DS636 | Generative Artificial Intelligence and Foundation Models | 2 0 3 | 3 |
| 26DS637 | Multimodal Artificial Intelligence | 2 0 3 | 3 |
| 26DS638 | Responsible Artificial Intelligence | 2 0 3 | 3 |
| 26DS639 | Agentic AI and Autonomous Agents | 2 0 3 | 3 |
| 26DS640 | AI Systems Engineering: DevOps, MLOps, DLOps | 2 0 3 | 3 |

**PROFESSIONAL ELECTIVES**

| Course Code | Title | L-T-P | Credit |
|---|---|---|---|
| 26DS731 | AI Applications for Power Systems | 2 0 3 | 3 |
| 26DS732 | Deep Learning in Genomics and Biomedicine | 2 0 3 | 3 |
| 26DS733 | Deep Learning for Biomedical Data Analysis | 2 0 3 | 3 |
| 26DS734 | Deep Learning for Speech Signal Processing | 2 0 3 | 3 |
| 26DS735 | Social Media Analytics | 2 0 3 | 3 |
| 26DS736 | Deep Learning for Visual Recognition | 2 0 3 | 3 |
| 26DS737 | Deep Learning for Cyber Security | 2 0 3 | 3 |
| 26DS738 | Complex Systems in Engineering, Finance & Biology: Modelling & Analysis | 2 0 3 | 3 |
| 26DS739 | High Performance Computing | 2 0 3 | 3 |
| 26DS740 | Multiscale Modelling in Fluid Dynamics | 2 0 3 | 3 |
| 26DS741 | Computer Vision | 2 0 3 | 3 |
| 26DS742 | Reinforcement Learning | 2 0 3 | 3 |
| 26DS743 | Blockchain Technology | 2 0 3 | 3 |
| 26DS744 | Predictive Analytics for Internet of Things | 2 0 3 | 3 |
| 26DS745 | Cloud Computing and Security in the Cloud | 2 0 3 | 3 |
| 26DS746 | Financial Data Analytics | 2 0 3 | 3 |
| 26DS747 | Material Informatics | 2 0 3 | 3 |
| 26DS748 | Integration of data science and system biology | 2 0 3 | 3 |
| 26DS749 | Introduction to Graph Theory | 2 0 3 | 3 |

**SEMESTER I**

| | | |
|---|---|---|
| **26MA603** | **Computational Mathematics for Data Science** | **L-T-P-C: 3-0-3-4** |

**Course Objectives**

- The course will lay down the basic concepts and techniques of linear algebra, calculus, and optimization theory needed for subsequent study.
- The course will explore these concepts initially through computational experiments and then develop an understanding of the underlying concepts and theory.
- The course will provide the background required to apply these methods in research work and/or practical applications.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Apply computational techniques and algebraic skills essential for the study of systems of linear equations, matrix algebra, vector spaces, eigenvalues and eigenvectors, orthogonality, diagonalization, and matrix projections.
- **CO2:** Analyze the role of single-variable and multivariable calculus in machine learning models.
- **CO3:** Solve constrained and unconstrained optimization problems using analytical and numerical optimization techniques relevant to data science.
- **CO4:** Develop data science algorithms by integrating concepts of linear algebra, calculus, and optimization.

**CO-PO Mapping**

| PO/PSO<br>CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | - | - | 3 | 1 | 1 |
| **CO2** | 2 | 3 | 1 | 1 | - | - | 2 | 2 | 1 |
| **CO3** | 2 | 3 | 2 | 2 | 1 | - | 3 | 3 | 1 |
| **CO4** | 3 | 3 | 3 | 2 | 1 | 1 | 3 | 3 | 2 |

**Syllabus**

**Unit I**

Matrices, rank, and Gaussian elimination; vector spaces and subspaces; linear independence, basis and dimension; four fundamental subspaces. Orthogonality, including perpendicular vectors and orthogonal subspaces, inner products and projections onto lines, projections and least-square applications, orthogonal basis, and Gram–Schmidt orthogonalization. Eigenvalues and eigenvectors, singular value decomposition, diagonal form of a matrix, and positive definite matrices including minima, maxima and saddle points, tests for positive definiteness, semi-definite and indefinite matrices.

**Unit II**

Introduction to single-variable calculus and multi-variable calculus. Introduction to mathematical optimization, least-squares and linear programming, convex and nonlinear optimization. Convex sets and convex optimization problems, optimization problems in standard form, convex optimization problems, quasi-convex optimization, linear optimization, quadratic optimization, and generalized inequality constraints.

**Unit III**

Unconstrained minimization techniques, including gradient descent method, conjugate gradient method, steepest descent method, and Newton's method. Formulation and analysis of optimization problems using the above iterative methods for solving linear, quadratic, convex, and nonlinear optimization problems.

**Textbooks / References**


1 *Gilbert Strang, Linear Algebra and its Applications, Fourth Edition, Cambridge University Press. 2009.*
2 *Gene H. Golub and V. Van Loan, Matrix Computations, Third Edition, John Hopkins University Press, Baltimore, 1996.*
3 *David C. Lay, Linear Algebra and Its Applications, Pearson Addison Wesley, 2002.*
4 *Strang, Gilbert. Linear algebra and learning from data. Cambridge: Wellesley-Cambridge Press, 2019.*
5 *Kalyanmoy, Deb. Optimization for engineering design: Algorithms and examples. Prentice-Hall of India Pvt. Limited, 2012.*
6 *Chong, Edwin KP, and Stanislaw H. Zak. An introduction to optimization. John Wiley & Sons, 2004.*
7 *Bhatti, M. Asghar. Practical Optimization Methods: With Mathematica® Applications. Springer Science & Business Media, 2012.*
8 *Stephen P. Boyd, and Lieven Vandenberghe. Convex optimization. Cambridge university press, 2004.*
9 *Nesterov, Yurii. Introductory lectures on convex optimization: A basic course. Vol. 87. Springer Science & Business Media, 2013.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment | Internal | Computational exercises using | 30% |

| | | | |
|---|---|---|---|
| – Lab (CAL) | | Python/MATLAB, mini computational tasks | |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project /<br>Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS601** | **Machine Learning** | **L-T-P-C: 3-0-3-4** |
|---|---|---|

**Course Objectives**

- This course provides the basic concepts of machine learning.
- This course provides the implementation of machine learning algorithms using MATLAB/Python.
- This course serves as a prerequisite for data analysis using machine learning algorithms.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Implement data pre-processing techniques for machine learning applications.
- **CO2:** Implement supervised machine learning algorithms for predictive modeling.
- **CO3:** Implement unsupervised machine learning algorithms for pattern discovery and clustering.
- **CO4:** Evaluate the performance of machine learning models using appropriate evaluation metrics.

**CO-PO Mapping**

| **PO/PSO** / **CO** | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PSO1** | **PSO2** | **PSO3** |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 2 | 2 | 3 | 1 | - | - | 2 | 3 | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CO2** | 3 | 3 | 3 | 2 | 1 | - | 2 | 3 | 1 |
| **CO3** | 3 | 3 | 3 | 2 | 1 | - | 2 | 3 | 1 |
| **CO4** | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Foundations of machine learning: Regression vs. Classification, Generalization, Training, Validation and Testing, Problem of Overfitting and mechanisms to overcome overfitting, Bias vs. Variance, vector independence, matrices and vector spaces, probability recap including conditional and joint probability. Data Handling: Datatypes and mathematical operations, scaling/normalization, binning and discretization, missing value imputation, and encodings.

**Unit II**

Supervised Learning: Classification algorithms including Support Vector Machines (SVM), Perceptron and Neural Networks, k-Nearest Neighbor (kNN) and weighted-kNN, Decision Trees (DT), Random Forest (RF), Boosting classifiers, Bayesian classifier and Naive-Bayes algorithm, Markov Model and Hidden Markov Model (HMM), and Stacking classifiers. Regression algorithms including linear, logistic, kNN, Random Forest, and SVM (Support Vector Machines). Clustering algorithms including partition algorithms and hierarchical algorithms.

**Unit III**

Performance metrics for Classification, Regression, and Clustering. Data Dimensionality including the curse of dimensionality and dimensionality reduction techniques. Machine learning algorithms applied for signal and image analysis.

**Textbooks / References**


1. *Tom Mitchell. Machine Learning. McGraw Hill; 2017*
2. *Trevor Hastie, Robert Tibshirani, Jerome Friedman. The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Springer, 2017.*
3. *Miroslav Kubat. An Introduction to Machine Learning. Springer, 2nd Edition 2017.*
4. *Christopher M Bishop. Pattern Recognition and Machine Learning. Springer, 2010.*
5. *Richard O. Duda, Peter E. Hart, David G. Stork. Pattern Classification. Wiley, Second Edition, 2007.*
6. *Kevin P. Murphey. Machine Learning, a probabilistic perspective. The MIT Press Cambridge, Massachusetts, 2012.*
7. *Mehryar Mohri, Afshin Rostamizadeh, Ameet Talwalkar. Foundations of Machine Learning. The MIT Press, 2018.*
8. *Lisa Tagliaferri, Michelle Morales, Ellie Birkbeck, Alvin Wan. Python Machine Learning Projects. DigitalOcean, 2019.*
9. *Andrew Ng. Machine Learning Yearning Technical Strategy for AI Engineers, In the Era of Deep Learning. 2018.*

10 *Soman, K. P., Loganathan, R., & Ajay, V, "Machine learning with SVM and other kernel methods", PHI Learning Pvt. Ltd., 1st Edition, 2009.*
11 *Soman, K. P., Shyam Diwakar, and V. Ajay. Data mining: theory and practice [with CD]. PHI Learning Pvt. Ltd., 1st Edition 2006.*

**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| 26DS602 | Foundations of Data Management | L-T-P-C: 3-0-3-4 |
|---|---|---|

**Course Objectives**

- This course aims to introduce the concepts of processing, storing, and retrieving data.

- This course will also familiarize students with fundamental data structures, information retrieval techniques, dimensionality reduction, and Database Management Systems (DBMS)
- The students will be motivated to apply these concepts to address diverse engineering and research challenges.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Select appropriate data structures for solving computational problems.
- **CO2:** Apply relational database concepts, including tables, relationships, and SQL queries, to solve engineering and research problems.
- **CO3:** Apply information retrieval techniques, including indexing, scoring, and ranking, to retrieve relevant information from datasets.
- **CO4:** Apply dimensionality reduction and noise elimination techniques for data preprocessing.

**CO-PO Mapping**

| PO / PSO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO** | | | | | | | | | |
| **CO1** | 2 | 3 | 3 | 2 | - | - | 2 | 2 | - |
| **CO2** | 3 | 3 | 3 | 2 | 1 | - | 2 | 2 | 1 |
| **CO3** | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 3 | 1 |
| **CO4** | 3 | 3 | 3 | 2 | 1 | 1 | 3 | 3 | 2 |

**Syllabus**

**Unit I**
Data Collection: Various sources and types of data: text, video, audio, biology etc; Data Preprocessing: Cleaning data, missing data imputation, noise elimination, feature selection and dimensionality reduction (PCA, tSNE, UMAP), normalisation. *Data Visualization:* histogram, pie chart, area-plot, box plot, scatter-plot, bubble plot, waffle charts etc.

**Unit II**
Data Structure: Stack, Queue, Linked List, Graphs. *Algorithms.* Searching, Sorting, Graph traversal, Complexity (Time)

**Unit III**

Database, Schema, ER diagram, SQL (Postgresql), database normalization (1NF,2NF,3NF and BCNF), indexing (B+tree), transaction concept and simple transaction model, serializability concept, concurrency control

**Textbooks / References**


1 *Introduction to Algorithms. Cormen, Leiserson, Rivest, Stein. MIT Press 3ed. ISBN-13: 978-0262533058*
2 *Database System Concepts. Silberschatz, Korth, Sudarshan. McGraw Hill Education; Sixth edition. ISBN-13: 978-9332901384*
3 *Introducing Data Science: Big Data, Machine Learning, and More, Using Python Tools. Cielen, Meysman,Ali. Dreamtech Press. ISBN-13: 978-9351199373*
4 *Data Engineering: A Novel Approach to Data Design. Brian Shive. Technics Publications. ISBN-13: 978-1935504603*
5 *Python Data Science Handbook: Essential Tools for Working with Data. Joel Grus. O'Reilly. ISBN-13: 978-9352134915*
6 *Jeff Erickson, "Algorithms", First edition, 2019 [Available on: https://jeffe.cs.illinois.edu/teaching/algorithms/book/Algorithms-JeffE.pdf]*
7 *Morin, Pat. Open Data Structures: An Introduction. Vol. 2. Athabasca University Press, 2013.*
8 *Michael T. Goodrich and Roberto Tamassia, "Algorithm Design Foundations, Analysis and Internet Examples," John Wiley and Sons, 2003.*
9 *Michael T. Goodrich and Roberto Tamassia, "Data Structures and Algorithms in Java," Fourth Edition, John Wiley, and Sons, 2004.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |

| | | | |
|---|---|---|---|
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project /<br>Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational compo nent depending on course delivery | 30% |

| **26RM605** | **Research Methodology** | **L-T-P-C: 2-0-0-2** |
|---|---|---|

**Course Objectives**

This course will

- Introduce the concepts involved in scientific research
- Explain the process of conducting a literature review for a given scientific problem
- Impart the fundamentals of scientific/technical writing

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Explain the fundamental concepts and methodologies of scientific research.
- **CO2:** Analyze the literature to identify research gaps and open problems in a chosen area of research.
- **CO3:** Prepare a research paper or dissertation to effectively communicate research contributions to the scientific community.

**CO-PO Mapping**

| **PO/PSO** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|

| CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 2 | 1 | - | 1 | 1 | 2 | 1 | 1 | 3 |
| **CO2** | 2 | 2 | 1 | 2 | 1 | 3 | 2 | 1 | 3 |
| **CO3** | 1 | 1 | - | 1 | 1 | 3 | 1 | 1 | 3 |

**Syllabus**

**Unit I**

Meaning of Research, types of research, research process, problem definition, objectives of research, research questions, research design, approaches to research, quantitative versus qualitative approach, understanding theory, building and validating theoretical models, exploratory versus confirmatory research, experimental versus theoretical research, and the importance of reasoning in research. Problem formulation, understanding modeling and simulation, conducting literature review, referencing, information sources, information retrieval, role of libraries in information retrieval, tools for identifying literature, indexing and abstracting services, and citation indexes.

**Unit II**

Experimental research including cause–effect relationships, development of hypotheses, measurement systems analysis, error propagation, validity of experiments, statistical design of experiments, field experiments, data and variable types and classification, data collection, numerical and graphical data analysis, sampling, observation, surveys, inferential statistics, and interpretation of results.

**Unit III**

Preparation of dissertations and research papers, tables and illustrations, guidelines for writing the abstract, introduction, methodology, results and discussion, and conclusion sections of a manuscript. References, citation and listing systems of documents. Intellectual Property Rights (IPR) including patents, copyrights, trademarks, industrial design, and geographical indication. Ethics of research, scientific misconduct, forms of scientific misconduct, plagiarism, unscientific practices in thesis work, and ethics in science.

**Textbooks / References**


1 *Bordens, K. S. and Abbott, B. B., "Research Design and Methods – A Process Approach", 8th Edition, McGraw-Hill, 2011*
2 *C. R. Kothari, "Research Methodology – Methods and Techniques," 2nd Edition, New Age International Publishers*
3 *Davis, M., Davis K., and Dunagan M., "Scientific Papers and Presentations", 3rd Edition, Elsevier Inc. Michael P. Marder, "Research Methods for Science", Cambridge University Press, 2011*
4 *T. Ramappa, "Intellectual Property Rights Under WTO," S. Chand, 2008*
5 *Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age." Aspen Law & Business; 6 edition July 2012.*

**SEMESTER II**

| 26DS611 | Deep Learning | L-T-P-C: 3-0-3-4 |
|---|---|---|

**Course Objectives**

- This course provides the basic concepts of deep learning and its implementation using MATLAB/Python.
- This course provides an understanding of the applications of deep learning algorithms in signal and image data analysis.
- This course covers deep learning algorithms such as transfer learning and attention models for signal and image analysis.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Implement fundamental deep neural network architectures for learning data representations.
- **CO2:** Implement convolutional neural network models for image and spatial data analysis.
- **CO3:** Implement sequential deep learning models for analyzing sequential and time-series data.
- **CO4:** Apply deep learning models to solve real-world problems.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | 1 | - | - | 2 | 3 | 1 |
| **CO2** | 3 | 3 | 3 | 2 | 1 | - | 2 | 3 | 1 |
| **CO3** | 3 | 3 | 3 | 2 | 1 | - | 2 | 3 | 2 |
| **CO4** | 3 | 3 | 3 | 3 | 1 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Perceptrons, Multilayer Perceptrons (MLPs), Sigmoid Neurons, Gradient Descent, Feedforward Neural Networks, and Backpropagation. Optimization techniques including Gradient Descent (GD), Stochastic Gradient Descent (SGD), AdaGrad, RMSProp, and Adam. Bias–Variance Tradeoff, L2 regularization, Early Stopping, Dataset Augmentation, Ensemble Methods, Dropout, Better Activation Functions, Better Weight Initialization Methods, and Batch Normalization.

**Unit II**

Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Backpropagation Through Time (BPTT), Vanishing and Exploding Gradients, Gated Recurrent Units (GRUs), and Long Short-Term Memory (LSTM) Cells.

**Unit III**

Encoder–Decoder Models, Attention Mechanism, and Transformers including Multi-Headed Self-Attention and Cross-Attention.

**Textbooks / References**


1. *Bishop C.M, "Pattern Recognition and Machine Learning", Springer, 1st Edition, 2006.*
2. *Goodfellow I, Bengio Y, Courville A, & Bengio Y, "Deep learning", Cambridge: MIT Press, 1st Edition, 2016.*
3. *Charu C. Aggarwal, "Neural Networks and Deep Learning", Springer, 2nd Edition, 2019.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |

| | | | |
|---|---|---|---|
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

**26DS631 Embedded Computing & RTOS for Data Science Applications L-T-P-C: 2-0-3-3**

**Course Objectives**

- The course will provide an understanding of the importance and applications of embedded systems in modern applications.
- The course will pave the way for understanding the various sources of data stream from an embedded system perspective and recording these data streams for processing.
- This will enable the students to develop various system and analyze data from the developed system for decision making.
- The course will enable the student with basic real-time operating system concepts for application development.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Explain the architecture of microcontrollers, their building components, and embedded data-streaming devices.
- **CO2:** Develop microcontroller-based applications for sensor interfacing and data streaming.
- **CO3:** Develop real-time data-streaming and intelligent applications using FreeRTOS.
- **CO4:** Develop real-time embedded system applications for healthcare, agriculture, autonomous vehicles, and other data-streaming domains.

**CO-PO Mapping**

| PO/PSO CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 1 | - | - | 1 | 2 | 1 |
| **CO2** | 2 | 3 | 3 | 2 | 1 | - | 2 | 3 | 1 |
| **CO3** | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 3 | 3 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Introduction to Embedded Systems, AI-enabled embedded system applications, embedded nodes as data sources in various applications, microcontrollers and their basics, microcontroller instruction set architecture (RISC and CISC), basic embedded processor/microcontroller architecture, memory system architecture including caches and virtual memory, memory devices and their characteristics such as RAM, ROM, UVROM, EEPROM, Flash Memory, and DRAM. I/O devices including timers and counters, watchdog timers, interrupt controllers, DMA controllers, A/D and D/A converters, displays, GPIO, analog sensor interfacing, and data recording.

**Unit II**

Networked embedded systems and protocols, real-time concepts, real-time operating systems, required RTOS services and capabilities in contrast with traditional operating systems. Software development for data acquisition, fundamentals of wireless networks for embedded systems, interfacing and integration of microcontroller-based systems, and examples of industrial process automation. Software development using Python and microcontrollers, introduction to data streams and analytics, and data visualization using Python tools.

**Unit III**

Machine learning techniques on sensor data streams. Introduction to hardware-accelerated embedded systems such as Jetson TX1, Raspberry Pi, and Jetson NANO for data science embedded application deployment.

**Textbooks / References**


1 *Amos, Brian, "Hands-On RTOS with Microcontrollers: Building real-time embedded systems using FreeRTOS, STM32 MCUs, and SEGGER debug tools", Packt Publishing Ltd, 2020.*
2 *Brian Amos, Jim Yuill, Penn Linder "Hands-On RTOS with Microcontrollers - Second Edition", Packt Publishing 2024.*
3 *Bhateja, Vikrant, Suresh Chandra Satapathy, and Hassan Satori, eds. Embedded Systems and Artificial Intelligence: Proceedings of ESAI 2019, Fez, Morocco. Vol. 1076. Springer Nature, 2020.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short | 20% |

| | | | |
|---|---|---|---|
| – Theory (CAT) | | tests (open/closed book), analytical exercises | |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

**26DS632 Introduction to Statistical Modeling and Probabilistic Graphical Models**

**L-T-P-C: 2-0-3- 3**

**Course Objectives**

- To provide a strong foundation in probability, statistical inference, and experimental design for analyzing uncertainty in data.
- To introduce probabilistic graphical models and Bayesian reasoning for representing and reasoning under uncertainty.
- To develop the ability to model, infer, and make decisions using graphical models and sequential probabilistic frameworks.

**Course Outcomes**

After completing this course, the students will be able to,

**CO1:** Apply concepts of probability, statistical distributions, estimation, hypothesis testing, and ANOVA for data analysis.

**CO2:** Analyze uncertainty using Bayesian reasoning, conditional probability, and probabilistic inference techniques.

**CO3:** Construct probabilistic graphical models, including Bayesian Networks, Markov Random Fields, and Factor Graphs.

**CO4:** Apply decision analysis, sampling techniques, and Markov models to solve real-world problems involving uncertainty and sequential data.

**CO-PO Mapping**:

| PO/PSO<br>CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | - | - | 3 | 1 | - |
| **CO2** | 3 | 2 | 2 | 2 | - | - | 2 | 2 | 1 |
| **CO3** | 2 | 3 | 3 | 3 | 1 | 1 | 3 | 3 | 2 |
| **CO4** | 1 | 3 | 2 | 3 | 2 | 1 | 3 | 3 | 2 |

**Syllabus**

**Unit I**

Probability theory, random variables, probability distributions, probability mass and density functions. Sampling techniques and empirical distributions. Estimation from sample data: point estimation, confidence intervals, and maximum likelihood estimation. Hypothesis testing: Z-test, t-test, Chi-square test. Analysis of Variance (ANOVA): single-factor, two-factor, and factorial designs.

**Unit II**

Joint, marginal, and conditional probability. Independence and conditional independence. Bayes' theorem and Bayesian inference. Introduction to probabilistic graphical models: directed graphical models (Bayesian Networks) and undirected graphical models (Markov Random Fields). Structured and unstructured graphical models, d-separation, partition functions, and inference in graphical models.

**Unit III**

Factor graphs and sampling methods for graphical models. Decision analysis using decision trees and influence diagrams. Markov processes and Markov chains. Applications of

probabilistic graphical models for uncertainty modeling, decision-making, and sequential data analysis.

**Textbooks / References**


1. *Trevor Hastie, Robert Tibshirani, Jerome Friedman. The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Springer, 2017.*
2. *Koller, Daphne, and Nir Friedman. Probabilistic graphical models: principles and techniques. MIT press, 2009.*
3. *Neapolitan, Richard E., and Xia Jiang. Artificial intelligence: With an introduction to machine learning. CRC press, 2018.*
4. *Ross, Kevin. "An introduction to Bayesian reasoning and methods." Bookdown. org (2022).*
5. *Karkera, Kiran R. Building probabilistic graphical models with Python. Packt Publishing, 2014.*
6. *Ankan, Ankur, and Abinash Panda. Mastering probabilistic graphical models using python. Packt Publishing Ltd, 2015.*
7. *Conrady, Stefan, and Lionel Jouffe. Bayesian networks and BayesiaLab: a practical introduction for researchers. Vol. 9. Franklin: Bayesia USA, 2015.*
8. *Christopher M Bishop. Pattern Recognition and Machine Learning. Springer, 2010.*


**Evaluation Pattern:**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |

| | | | |
|---|---|---|---|
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project /<br>Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS633** | **Scientific Computing** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- This course helps students understand established conventional computational techniques.
- This course helps students understand the concepts related to probability, statistics, linear algebra and partial differential equations, as well as the methods used to solve these equations.
- This course aims to help students implement computational methods using MATLAB and Python.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Develop mathematical models to describe natural/engineering/physical systems.
- **CO2:** Solve differential equations using numerical schemes.
- **CO3:** Analyze the stability of systems using dynamical systems theory.
- **CO4:** Develop data-driven models of different engineering/natural/physical systems.

**CO-PO Mapping**

| **PO/PSO CO** | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PSO1** | **PSO2** | **PSO3** |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 2 | - | - | 3 | 1 | 2 |
| **CO2** | 3 | 3 | 3 | 2 | - | - | 3 | 1 | 2 |
| **CO3** | 3 | 3 | 2 | 3 | 1 | - | 3 | 2 | 2 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CO4** | 2 | 3 | 3 | 3 | 1 | 1 | 3 | 3 | 3 |

**Syllabus**

**Unit I**

Introduction to Mathematical Modelling, linear systems of equations, eigenvalues and eigenvectors, stability of systems using eigenvalue analysis, Taylor series, numerical differentiation, numerical integration, and higher-order accuracy schemes for integration and differentiation.

**Unit II**

Ordinary Differential Equations (ODEs), Partial Differential Equations (PDEs), iterative methods, numerical methods including error analysis, stability and convergence, and Runge–Kutta methods.

**Unit III**

Data-driven modelling, Dynamic Mode Decomposition (DMD), Koopman Theory, system identification techniques for nonlinear systems, and Physics-Informed Neural Networks.

**Textbooks / References**


1 *Gilbert Strang, Differential Equations and Linear Algebra, Wellesley-Cambridge Press, 2015.*
2 *Kutz, J. Nathan, Data-Driven Modeling & Scientific Computation: Methods for Complex Systems & Big Data, Oxford University press, 2013.*
3 *Arfken, George. B., and Weber, Hans. J., Mathematical Methods for Physicists, Sixth Edition, Elsevier Academic Press, 2005.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |

| | | | |
|---|---|---|---|
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project /<br>Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational compo nent depending on course delivery | 30% |

| **26DS634** | **Text Mining and Analytics** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- This course aims to provide an insight into the concepts of Natural Language Processing (NLP) and its applications.
- This course helps students implement NLP applications using deep learning algorithms.
- This course helps students understand various word/text representation algorithms.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Apply word and text representation techniques to capture semantic relationships in textual data.
- **CO2:** Model natural language processing tasks using machine learning, deep learning, and large language models.
- **CO3:** Implement deep learning models for text mining and real-world text analytics applications.
- **CO4:** Evaluate natural language processing models using appropriate performance metrics and visualization techniques.

**CO-PO Mapping**

| **PO/PSO**<br>**CO** | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PSO1** | **PSO2** | **PSO3** |
|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 1 | - | - | 2 | 2 | 1 |
| **CO2** | 3 | 3 | 3 | 2 | 1 | - | 2 | 3 | 2 |
| **CO3** | 2 | 3 | 3 | 3 | 1 | 1 | 2 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 2 | 1 | 2 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Introduction to Natural Language Processing (NLP), words, n-grams, language modelling, part-of-speech tagging, information extraction, named entity recognition, relation extraction, syntactic and semantic parsing, and morphological analysis. Introduction to NLP tools such as NLTK and spaCy for basic NLP tasks. Text representation and transformation including vector space models, Bag-of-Words, Term Frequency (TF), and Inverse Document Frequency (IDF).

**Unit II**

Word vector representations including Word2Vec, GloVe, FastText, BERT, ALBERT, and RoBERTa. Word representations for Indic languages including IndicBERT, IndicFT, XLM, and MuRIL. Topic Modelling using Latent Dirichlet Allocation (LDA).

**Unit III**

Neural language models including Recurrent Neural Networks (RNNs), Long Short-Term Memory (LSTM) Networks, encoder–decoder architecture, attention mechanism, and transformer networks. Large Language Models (LLMs), zero-shot learning, few-shot learning, and fine-tuning of LLMs. Applications including text classification, sentiment analysis, neural machine translation, question answering, and text summarization.

**Textbooks / References**


1 *Daniel Jurafsky and James H. Martin, "Speech and Language Processing," 3rd edition, 2026. [Available on: https://web.stanford.edu/~jurafsky/slp3/ed3book_dec302020.pdf]*
2 *Christopher Manning and Hinrich Schutze, "Foundations of statistical natural language processing," MIT press, 1999.*
3 *Jacob Eisenstein, "Introduction to natural language processing," Illustrated edition, The MIT press, 2019.*
4 *Bengfort, Benjamin, Rebecca Bilbro, and Tony Ojeda. Applied text analysis with python: Enabling language-aware data products with machine learning. " O'Reilly Media, Inc.", 2018.*
5 *Ronan Collobert, Jason Weston, Léon Bottou, Michael Karlen, Koray Kavukcuoglu, and Pavel Kuksa, "Natural language processing (almost) from scratch," Journal of machine learning research 12, no. ARTICLE (2011): 2493-2537.*
6 *Yoav Goldberg, "Neural network methods for natural language processing," Synthesis lectures on human language technologies 10, no. 1 (2017): 1-309.*
7 *Yoav Goldberg, "A primer on neural network models for natural language processing," Journal of Artificial Intelligence Research 57 (2016): 345-420.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| 26DS635 | Bigdata Framework for Data Science | L-T-P-C: 2-0-3-3 |
|---|---|---|

**Course Objectives**

- To understand the importance of functional programming.
- To implement various big data concepts using Scala programming language, which is a functional programming language.
- To develop the ability to solve various real-time problems using big data concepts.

**Course Outcomes**

After completing this course, the students will be able to,

**CO1:** Explain functional programming concepts and representations.

**CO2:** Model computations using the MapReduce programming paradigm.
**CO3:** Develop programs using big data tools for data manipulation.
**CO4:** Analyze large-scale datasets using appropriate big data processing techniques.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 1 | - | - | 2 | 2 | 1 |
| **CO2** | 2 | 3 | 3 | 2 | - | - | 2 | 3 | 1 |
| **CO3** | 2 | 3 | 3 | 2 | 1 | - | 2 | 3 | 1 |
| **CO4** | 2 | 3 | 3 | 3 | 2 | 1 | 3 | 3 | 2 |

**Syllabus**

**Unit I**
Introduction to Big Data, characteristics of Big Data, Big Data Analytics, typical analytical architecture, challenges in Big Data Analytics, and the need for Big Data frameworks. Big Data using functional programming in Scala, including loops, lazy evaluation, arrays, strings and collections, classes and objects, functions, recursion, tail recursion, higher-order functions, curried functions, closures, inheritance, overloading and overriding, traits, maps, flatmaps, sequence summations using reduce, fold, scan, and filter.

**Unit II**
Apache Hadoop framework, requirements of the Hadoop framework, design principles of Hadoop, comparison with other systems, Hadoop components, Hadoop 1.0 vs Hadoop 2.0 vs Hadoop 3.0, Hadoop daemons, HDFS commands, MapReduce programming, pipelining MapReduce jobs, Hadoop installation, and programming.

**Unit III**
Apache Spark framework, Resilient Distributed Datasets (RDDs), creating RDDs, lineage and fault tolerance, DAGs, Spark programming, application execution, transformations and actions, persistence, setting up a standalone Spark cluster, spark-shell, basic API, modules core, key/value pairs and other RDD features, DataFrames and Datasets, creating DataFrames from RDDs, using Spark SQL to query DataFrames, NoSQL aggregate databases, MLlib examples on regression, classification and clustering problems, and analytics case studies.

**Textbooks / References**


1 *Big Data: Principles and best practices of scalable realtime data systems by James Warren, Nathan Marz, 2015.*
2 *Learning Spark: Lightning-Fast Big Data Analysis, 1st Edition by Holden Karau, Andy Konwinski, Patrick Wendell, 2015.*
3 *Programming in Scala: A Comprehensive Step-by-Step Guide, 4th Edition by Martin Odersky, Lex Spoon, Bill Venners.*

4 *High Performance Spark: Best Practices for Scaling and Optimizing Apache Spark, 1st Edition by Holden Karau, Rachel Warren.*
5 *Scala for the Impatient, 3rd Edition by Cay S. Horstmann*
6 *Spark: The Definitive Guide: Big Data Processing Made Simple 1st Edition (Kindle Edition) by Bill Chambers, Matei Zaharia.*

**Evaluation Pattern**

| **Assessment component** | **Internal / External** | **Suggested Assessment Methods** | **Weightage (%)** |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

**26DS636 Generative Artificial Intelligence and Foundation Models L-T-P-C: 2-0-3-3**

**Course Objectives**

- To introduce the theoretical foundations and architectures of modern Generative AI systems and foundation models.
- To develop expertise in building, adapting, and evaluating foundation models for diverse modalities.
- To enable students to implement prompting, fine-tuning, retrieval augmentation, and alignment techniques.
- To familiarize students with deployment, safety, efficiency, and emerging applications of Generative AI.

**Course Outcomes**

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

- **CO1**: Analyze architectures and learning paradigms of foundation models and generative AI systems.
- **CO2**: Implement generative models for text, image, audio, and multimodal content generation.
- **CO3**: Develop domain-specific generative AI applications using prompting, fine-tuning, and retrieval augmentation techniques.
- **CO4**: Evaluate performance, safety, alignment, and efficiency of foundation models.

**CO-PO Mapping**

| PO/PSO<br>CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 |
| **CO2** | 3 | 3 | 3 | 2 | 3 | 2 | 2 | 3 | 2 |
| **CO3** | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 3 | 3 | 3 | 1 | 2 | 3 |

**Syllabus**

**Unit I**

Introduction to Generative AI; Discriminative vs Generative Learning; Representation Learning; Self-Supervised Learning; Scaling Laws; Emergence and In-Context Learning; Foundation Models; Neural Language Models; Word Embeddings and Contextual Representations; Transformer Architecture; Attention Mechanisms; Encoder-only, Decoder-

only and Encoder-Decoder Models; Large Language Models (LLMs); Foundation Models for Vision, Speech, and Multimodal Data.

**Unit II**

Autoregressive Models; Variational Autoencoders (VAEs); Generative Adversarial Networks (GANs); Diffusion Models; Text Generation Models; Image Generation Models; Speech and Audio Generation Models; Prompt Engineering; Chain-of-Thought Prompting; In-Context Learning; Parameter-Efficient Fine-Tuning (PEFT); LoRA and QLoRA; Instruction Tuning; Reinforcement Learning from Human Feedback (RLHF); Retrieval-Augmented Generation (RAG); Knowledge-Augmented Generation. KV Cache and attention optimization techniques, Efficient transformer inference, Memory optimization for LLM serving

**Unit III**

Multimodal Foundation Models; Vision-Language Models; Text-to-Image Systems; Image Captioning; Visual Question Answering; Text-to-Speech and Speech-to-Text Models; Evaluation Metrics for Generative Models; Hallucination Detection and Mitigation; Model Compression and Quantization

**Textbooks/References**


1. *Huyen, Chip, AI engineering: Building applications with foundation models, O'Reilly Media, Inc., 2024.*
2. *Rothman, Denis. Transformers for Natural Language Processing and Computer Vision: Explore Generative AI and Large Language Models with Hugging Face, ChatGPT, GPT-4V, and DALL-E 3. Packt Publishing Ltd, 2024.*
3. *Rothman, Denis, RAG-Driven Generative AI: Build custom retrieval augmented generation pipelines with LlamaIndex, Deep Lake, and Pinecone. Packt Publishing Ltd, 2024.*
4. *Sanseviero, Omar, Pedro Cuenca, Apolinário Passos, and Jonathan Whitaker, Hands-on generative AI with transformers and diffusion models, O'Reilly Media, Inc., 2024.*
5. *Tunstall, Lewis, Leandro Von Werra, and Thomas Wolf, Natural language processing with transformers, O'Reilly Media, Inc., 2022.*
6. *Jurafsky, Daniel, and James H. Martin, Speech and language processing 3rd edition draft, October 2019 (2019).*
7. *Brown, T., Mann, B., Ryder, N., Subbiah, M., Kaplan, J.D., Dhariwal, P., Neelakantan, A., Shyam, P., Sastry, G., Askell, A. and Agarwal, S, Language models are few-shot learners. Advances in neural information processing systems 33 (2020): 1877-1901.*


**Evaluation Pattern**

| Component | Internal/External | Suggested Assessment Methods | Weightage |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

**26DS637 Multimodal Artificial Intelligence L-T-P-C: 2-0-3-3**

**Course Objectives:**

- To introduce the fundamental concepts, challenges, and architectures of multimodal learning involving vision, audio, and text data.
- To develop an understanding of multimodal fusion, alignment, and heterogeneous data representation techniques for integrating information from multiple modalities.
- To equip students with knowledge transfer strategies and domain-specific applications of multimodal AI for solving real-world problems.

**Course Outcomes:**

Upon successful completion of the course, students will be able to:

- **CO1:** Explain the principles, challenges, datasets, and foundational models associated with multimodal AI systems.

- **CO2:** Develop multimodal fusion and alignment techniques for integrating heterogeneous data sources.
- **CO3:** Apply cross-modal knowledge transfer methods, including co-learning, self-training, and multitask learning, to enhance learning across modalities.
- **CO4:** Develop multimodal AI solutions for domain-specific applications while considering interpretability, explainability, and responsible AI practices.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 1 | 1 | - | - | - | 2 | 1 | 1 |
| **CO2** | 2 | 3 | 3 | 2 | - | - | 3 | 3 | 1 |
| **CO3** | 2 | 3 | 2 | 3 | 1 | - | 3 | 3 | 2 |
| **CO4** | 1 | 3 | 2 | 3 | 3 | 1 | 3 | 3 | 2 |

**Unit I**

Introduction to Multimodal learning - Core challenges, information redundancy, uniqueness, and synergy across data sources; Multimodal Datasets - Research tasks, data collection guidelines, and data processing/visualization; Unimodal foundations - Review of dimensions of heterogeneity and common model architectures for vision, audio, and text;

**Unit II**

Fusion Paradigms – Early, Late and explainable fusion techniques; Advanced Fusion Modeling – Higher-order interactions and specialized multimodal fusion architectures; Multimodal alignment – Heterogeneous Data Representation.

**Unit III**

Cross-Modal Transfer: Modality transfer, co-learning, self-training, and multitask learning to move knowledge from high-resource to low-resource data; Multimodal domain specific applications.

**References:**


1. *Tjandrasuwita, Megan, Chanakya Ekbote, Liu Ziyin, and Paul Pu Liang. "Understanding the emergence of multimodal representation alignment." arXiv preprint arXiv:2502.16282 (2025).*
2. *Lee, Jimin, Steven-Shine Chen, and Paul Pu Liang. "Interactive sketchpad: A multimodal tutoring system for collaborative, visual problem-solving." In Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems, pp. 1-14. 2025.*
3. *Liang, Paul Pu, Amir Zadeh, and Louis-Philippe Morency. "Foundations & trends in multimodal machine learning: Principles, challenges, and open questions." ACM computing surveys 56, no. 10 (2024): 1-42.*
4. *Team, Chameleon. "Chameleon: Mixed-modal early-fusion foundation models." arXiv preprint arXiv:2405.09818 (2024).*
5. *Kim, Moo Jin, Karl Pertsch, Siddharth Karamcheti, Ted Xiao, Ashwin Balakrishna, Suraj Nair, Rafael Rafailov et al. "Openvla: An open-source vision-language-action model." arXiv preprint arXiv:2406.09246 (2024).*
6. *Dong, Runpei, Yuang Peng, Zekun Qi, Zheng Ge, Jinrong Yang, Liang Zhao, Jianjian Sun et al. "Dreamllm: Synergistic multimodal comprehension and creation." In International Conference on Learning Representations, vol. 2024, pp. 6666-6702. 2024.*
7. *Liang, Paul Pu, Yun Cheng, Xiang Fan, Chun Kai Ling, Suzanne Nie, Richard Chen, Zihao Deng et al. "Quantifying & modeling multimodal interactions: An information decomposition framework." Advances in Neural Information Processing Systems 36 (2023): 27351-27393.*
8. *Hessel, Jack, and Lillian Lee. "Does my multimodal model learn cross-modal interactions? It's harder to tell than you might think!." In Proceedings of the 2020 Conference on Empirical Methods in Natural Language Processing (EMNLP), pp. 861-877. 2020.*
9. *Baltrušaitis, Tadas, Chaitanya Ahuja, and Louis-Philippe Morency. "Multimodal machine learning: A survey and taxonomy." IEEE transactions on pattern analysis and machine intelligence 41, no. 2 (2018): 423-443.*
10. *Zaheer, Manzil, Satwik Kottur, Siamak Ravanbakhsh, Barnabas Poczos, Russ R. Salakhutdinov, and Alexander J. Smola. "Deep sets." Advances in neural information processing systems 30 (2017).*
11. *Turk, Matthew. "Multimodal interaction: A review." Pattern recognition letters 36 (2014): 189-195.*
12. *Bengio, Yoshua, Aaron Courville, and Pascal Vincent. "Representation learning: A review and new perspectives." IEEE transactions on pattern analysis and machine intelligence 35, no. 8 (2013): 1798-1828.*

**Evaluation Pattern**

| Component | Internal/External | Suggested Assessment Methods | Weightage |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

**26DS638 Responsible Artificial Intelligence L-T-P-C: 2-0-3-3**

**Course Objectives**

- To introduce the principles, frameworks, and governance mechanisms of Responsible AI.
- To equip students with methodologies for identifying and mitigating bias, unfairness, and risks in AI systems.
- To develop skills for designing transparent, explainable, privacy-preserving, and trustworthy AI solutions.

**Course Outcomes**

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

- **CO1**: Analyze ethical, societal, legal, and regulatory challenges associated with AI systems.
- **CO2**: Assess fairness, bias, accountability, transparency, and privacy risks in AI models.
- **CO3**: Develop responsible AI solutions incorporating explainability, robustness, security, and governance mechanisms.
- **CO4**: Evaluate AI systems using established Responsible AI frameworks, standards, and auditing methodologies.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 1 | 2 |
| **CO2** | 3 | 3 | 3 | 2 | 3 | 2 | 2 | 2 | 2 |
| **CO3** | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 3 | 3 | 3 | 1 | 2 | 3 |

**Syllabus**

**Unit I**

Introduction to Responsible AI; History and Evolution of AI Ethics; Ethical Theories and AI; Human-Centered AI; Principles of Responsible AI—Fairness, Accountability, Transparency, Explainability, Privacy, Safety, Robustness, Inclusiveness, Sustainability; Stakeholders in AI Ecosystems; Societal Impacts of AI; AI Risks and Harms; Responsible AI Frameworks from OECD, UNESCO, NIST, IEEE, European Union, and Government of India.

**Unit II**

Sources of Bias in Data and Algorithms; Fairness Metrics; Algorithmic Fairness; Bias Detection and Mitigation Techniques; Explainable AI (XAI); Interpretable Machine Learning; SHAP, LIME, Counterfactual Explanations; Privacy-Preserving AI; Differential Privacy; Federated Learning; Data Governance; Security and Adversarial Attacks; Robustness Evaluation; Trustworthy AI Systems.

**Unit III**

AI Regulations and Policies; EU AI Act; NIST AI Risk Management Framework; ISO/IEC Standards for AI Governance; AI Auditing and Impact Assessment; Documentation and Model Cards; Data Sheets for Datasets; Responsible Generative AI; Responsible LLM Development and Deployment; AI Safety and Alignment; Red Teaming; Monitoring and Continuous Risk Assessment; Responsible AI in Healthcare, Finance, Education, Social Media, Cybersecurity, and Public Governance.

**Textbooks/References**


1. *Dignum, Virginia. Responsible artificial intelligence: How to develop and use AI in a responsible way. Vol. 2156. Cham: Springer, 2019.*
2. *Coeckelbergh, Mark, Mark Coeckelbergh: AI Ethics, 2021*
3. *Barocas, Solon, Moritz Hardt, and Arvind Narayanan, Fairness and machine learning, 2019*
4. *Ammanath, Beena. Trustworthy AI: a business guide for navigating trust and ethics in AI. John Wiley & Sons, 2022.*
5. *Floridi, Luciano, The ethics of artificial intelligence: Principles, challenges, and opportunities, 2023*
6. *Molnar, Christoph, Interpretable machine learning. A Guide for Making Black Box Models Explainable, 2019. https://christophm.github.io/interpretable-ml-book/.*


**Evaluation Pattern**

| Component | Internal/External | Suggested Assessment Methods | Weightage |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |

| | | | |
|---|---|---|---|
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

**26DS639 Agentic AI Systems and Autonomous Agents L-T-P-C: 2-0-3-3**

**Course Objectives**

- To introduce the concepts, architectures, and design principles of intelligent autonomous agents and agentic AI systems.
- To develop AI agents capable of planning, reasoning, memory management, and tool utilization using Large Language Models (LLMs).
- To enable students to design multi-agent systems for solving complex real-world problems.

**Course Outcomes**

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

- **CO1**: Analyze intelligent agent architectures, planning mechanisms, reasoning strategies, and decision-making processes.
- **CO2**: Develop LLM-powered autonomous agents with memory, retrieval, and tool-use capabilities.
- **CO3**: Construct multi-agent systems for collaborative problem solving and workflow automation.
- **CO4**: Evaluate safety, ethics, governance, and deployment aspects of agentic AI systems.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 2 | 2 | 1 | 2 | 1 | 2 |
| **CO2** | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 2 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CO3** | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 |
| **CO4** | 2 | 3 | 2 | 3 | 3 | 3 | 1 | 2 | 3 |

**Syllabus**

**Unit I**

Introduction to Artificial Intelligence Agents; Rational Agents; Agent Environment; Agent Architectures; Reactive, Deliberative, Hybrid and Learning Agents; Goal-based and Utility-based Agents; Knowledge Representation and Reasoning; Search and Planning; Markov Decision Processes; Reinforcement Learning Foundations; Large Language Models as Cognitive Engines; Emergence of Agentic AI; Prompt Engineering for Autonomous Agents.

**Unit II**

Agentic Workflows; ReAct Framework; Chain-of-Thought Reasoning; Tool Use and Function Calling; Retrieval Augmented Generation (RAG); Agent Memory Architectures (Short-term, Long-term, Vector Memory); Autonomous Task Planning and Execution; Agent Frameworks (LangChain, LangGraph, CrewAI, AutoGen, Semantic Kernel); Web Search and API Integration; Agent Evaluation Metrics.

**Unit III**

Multi-Agent Systems (MAS); Communication Protocols; Cooperative and Competitive Agents; Agent Coordination and Negotiation; Swarm Intelligence Concepts; Human-Agent Collaboration; AI Safety and Alignment; Hallucination Mitigation; Explainability and Trustworthiness; Ethical and Responsible AI; Governance of Autonomous Systems; AgentOps and Deployment; Applications in Healthcare, Finance, Education, Social Media Analytics, Cybersecurity, Robotics, and Scientific Discovery.

**Textbooks/References**


1. *Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach, 4th Edition, Pearson, 2021.*
2. *Wooldridge, Michael. An introduction to multiagent systems. John wiley & sons, 2009.*
3. *Biswas, Anjanava, and Wrick Talukdar. Building Agentic AI Systems: Create intelligent, autonomous AI agents that can reason, plan, and adapt. Packt Publishing Ltd, 2025.*
4. *Auffarth, Ben, and Leonid Kuligin, Generative AI with LangChain: Build production-ready LLM applications and advanced agents using Python, LangChain, and LangGraph, 2025*


**Evaluation Pattern**

| Component | Internal/External | Suggested Assessment Methods | Weightage |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

**26DS640 AI Systems Engineering: DevOps, MLOps, DLOps L-T-P-C: 2-0-3-3**

**Course Objectives**

- To introduce software engineering principles for scalable AI system development and deployment.
- To develop expertise in DevOps, MLOps, and DLOps pipelines for machine learning and deep learning applications.
- To enable students to design, automate, monitor, and manage the lifecycle of AI systems in production environments.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Analyze software engineering, DevOps, MLOps, and DLOps practices for AI system development.

- **CO2:** Develop automated pipelines for data, model training, testing, deployment, and monitoring.
- **CO3:** Implement scalable AI applications using cloud-native and containerized infrastructures.
- **CO4:** Evaluate operational performance, reliability, security, and governance of AI systems.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 1 |
| **CO2** | 3 | 3 | 3 | 2 | 3 | 2 | 2 | 3 | 2 |
| **CO3** | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 3 | 3 | 3 | 1 | 2 | 3 |

**Syllabus**

**Unit I**

Introduction to AI Systems Engineering; Software Engineering for AI Applications; AI System Lifecycle; DevOps Principles and Practices; Agile Development; Version Control using Git; Continuous Integration (CI); Continuous Delivery and Deployment (CD); Infrastructure as Code; Configuration Management; Containerization using Docker; Container Orchestration using Kubernetes; Microservices Architecture; Cloud-Native AI Systems; Software Testing and Quality Assurance for AI Applications.

**Unit II**

Introduction to MLOps and DLOps; Data Versioning and Data Management; Feature Engineering Pipelines; Experiment Tracking; Model Versioning; Reproducible Machine Learning; Automated Training Pipelines; Hyperparameter Optimization; Workflow Orchestration; ML Metadata Management; Deep Learning Lifecycle Management; Distributed Deep Learning; GPU Resource Management; Model Packaging and Serving; MLOps Platforms (MLflow, Kubeflow, Weights & Biases, DVC, Airflow).

**Unit III**

Model Serving Architectures; REST APIs for AI Models; Edge and Cloud Deployment; Model Monitoring; Concept Drift and Data Drift Detection; Performance Monitoring; Observability and Logging; AI System Reliability; Security in AI Pipelines; Responsible AI Operations; Model Governance; Explainability in Production Systems; Compliance and Auditability; Cost

Optimization; AIOps; LLMOps and Foundation Model Deployment; AgentOps for Autonomous AI Systems; Case Studies in Healthcare, Finance, Manufacturing, Social Media Analytics, and Cybersecurity.

**Textbooks/References**


1. *Gift, Noah, and Alfredo Deza, Practical MLOps, O'Reilly Media, Inc., 2021.*
2. *Treveil, Mark, Nicolas Omont, Clment Stenac, Kenji Lefevre, D. Phan, J. Zentici, A. Lavoillotte, M. Miyazaki, and L. Heidmann, Introducing MLOps, O'Reilly Media, 2020.*
3. *Brikman, Yevgeniy, Terraform: up and running: writing infrastructure as code, O'Reilly Media, Inc., 2022.*
4. *Hoffman, Andrew, Web application security, O'Reilly Media, Inc., 2024.*
5. *Lakshmanan, Valliappa, Sara Robinson, and Michael Munn, Machine learning design patterns, O'Reilly Media, 2020.*
6. *Huyen, Chip, Designing machine learning systems, O'Reilly Media, Inc., 2022.*
7. *Burns, Brendan, Joe Beda, Kelsey Hightower, and Lachlan Evenson, Kubernetes: up and running: dive into the future of infrastructure, O'Reilly Media, Inc., 2022.*
8. *Aryan, Abi, LLMOps: Managing Large Language Models in Production, O'Reilly Media, Inc., 2025.*
9. *Kim, Gene, Jez Humble, Patrick Debois, John Willis, and Nicole Forsgren, The DevOps handbook: How to create world-class agility, reliability, & security in technology organizations, IT Revolution, 2021.*


**Evaluation Pattern**

| Component | Internal/External | Suggested Assessment Methods | Weightage |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |

| | | | |
|---|---|---|---|
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

**PROFESSIONAL ELECTIVES**

| **26DS731** | **AI Applications for Power Systems** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- The course provides a fundamental understanding of electric power systems and the underlying dynamics of their operation.
- The course will impart the basic concepts and principles of power system analysis.
- The course will provide knowledge of appropriate AI frameworks for solving power system problems.
- The course will empower students to integrate power system concepts into AI research.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Explain the fundamental concepts about conventional power systems and smart grids.
- **CO2:** Analyze the mathematical models underlying power grid operation, including economic dispatch and optimal power flow optimization problems.

- **CO3:** Apply AI frameworks to solve power system problems.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | 2 | - | 2 | 1 | 1 |
| **CO2** | 3 | 3 | 2 | 2 | 2 | - | 3 | 2 | 1 |
| **CO3** | 2 | 3 | 3 | 3 | 2 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Three-phase systems, overview of the power grid, complex power, per-unit systems, optimization principles, economic dispatch, power flow analysis, and optimal power flow (OPF).

**Unit II**

Fundamentals of power system stability, distribution systems, microgrids and energy storage, electric power markets, renewable energy optimization, and forecasting of renewable energy sources.

**Unit III**

Artificial Intelligence (AI) for demand-side management and other AI applications in power systems, including hydro-thermal scheduling, transmission planning, maintenance scheduling, and related power system optimization problems.

**Textbooks / References**


1 *Arthur R. Bergen, and Vijay Vittal. Power systems analysis. Prentice Hall, 2000.*
2 *Stephen P. Boyd, and Lieven Vandenberghe. Convex optimization. Cambridge university press, 2004.*
3 *Allen J. Wood and Bruce Wollenberg. Power Generation Operation and Control. Wiley Press, 2006.*
4 *Kevin Warwick. Artificial Intelligence Techniques in Power Systems. IET Power and Energy Series, 2008.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment | Internal | Problem-solving assignments, quizzes | 20% |

| | | | |
|---|---|---|---|
| – Theory (CAT) | | (conceptual & numerical), short tests (open/closed book), analytical exercises | |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS732** | **Deep Learning in Genomics and Biomedicine** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- The course will lay down the basic concepts and techniques of deep learning in Genomics and Biomedicine
- The course will examine how both deep learning and traditional machine learning models can be used to solve key problems in genomics and biomedicine, while contrasting and comparing their strengths and weaknesses.
- The goal of the course is to enable students to apply the concepts and techniques of deep learning in genomics and biomedicine.

**Course Outcomes:**

After completing this course, the students will be able to,

- **CO1:** Develop an understanding of the basic concepts in genomics and biomedicine.

- **CO2:** Use various feature representation schemes to represent biomolecular and genomics datasets.
- **CO3:** Implement deep learning algorithms for genomics data analysis.
- **CO4:** Apply appropriate deep learning algorithms for biomedicine and drug design.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | 2 | - | 2 | 1 | 1 |
| **CO2** | 2 | 3 | 3 | 2 | 1 | - | 2 | 3 | 1 |
| **CO3** | 2 | 3 | 3 | 3 | 1 | 1 | 2 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 3 | 3 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Gene, genome and genomics; DNA, RNA and proteins; transcription factor (TF) binding, chromatin accessibility and RNA interference; protein sequence, protein structure and protein binding. Review of machine learning and deep learning including training, validation, regularization, and hyperparameter optimization. Introduction to DeepChem and prediction of toxicity of molecules. MoleculeNet, featurizing a molecule, SMILES strings, RDKit, ECFPs, molecular descriptors, and graph convolutions.

**Unit II**

DenseNets and Convolutional Neural Networks (CNNs) for genomics, Recurrent Neural Networks (RNNs), autoencoders and representation learning. Variational autoencoders and generative models, generating new ideas for lead compounds, protein design, and training a variational autoencoder to generate new molecules.

**Unit III**

Pretraining and fine-tuning, transformer-based models, BERT, one-shot learning for drug discovery, and case studies in drug discovery applications.

**Textbooks / References**


1 *Bharath Ramsundar, Peter Eastman, Patrick Walters, and Vijay Pande, "Deep Learning for the Life Sciences: Applying Deep Learning to Genomics, Microscopy, Drug Discovery, and More", O'Reilly Media, Inc. 2019.*

2 *Sukumar, N., Anandaram, H., and Bhadra, P. "Computational Drug Discovery – A Primer" (Ion Cures Press, 2023). ISBN: 979-8850083663*

3 *Goodfellow I, Bengio Y, Courville A, & Bengio Y, "Deep learning", Cambridge: MIT Press, 1st Edition, 2016.*

4 *Michael Nielsen, "Neural Networks and Deep Learning", Goodreads (eBook), 2013.*

5 *Bengio Y, "Learning Deep Architectures for AI, Foundations and Trends in Machine Learning", nowpublishers, 2009.*
6 *Vaswani, A., et al. "Attention Is All You Need." arXiv:1706.03762v5 [cs.CL] 6 Dec 2017*
7 *Bagal, V., Aggarwal, R., Vinod, P. K. and U. Priyakumar, Deva, "MolGPT: Molecular Generation Using a Transformer-Decoder Model." J. Chem. Inf. Model. 2022, 62, 2064−2076 https://doi.org/10.1021/acs.jcim.1c00600*
8 *ChemBERTa: Large-Scale Self-Supervised Pretraining for Molecular Property Prediction using a Smiles Tokenization Strategy.*
9 https://github.com/deepchem/deepchem/blob/master/examples/tutorials/Transfer_Learning_With_ChemBERTa_Transformers.ipynb
10 *Weblink: https://genome.cshlp.org/content/26/7/990*
11 *Weblink: https://www.nature.com/articles/nmeth.3547*
12 *Weblink: https://academic.oup.com/nar/article/44/11/e107/2468300*
13 *Weblink: https://arxiv.org/abs/1512.00843*

**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small | 30% |

| | | | |
|---|---|---|---|
| | | computational compo nent depending on course delivery | |

| 26DS733 | Deep Learning for Biomedical Data Analysis | L-T-P-C: 2-0-3-3 |
|---|---|---|

**Course Objectives**

- This course teaches the application of state-of-the-art deep learning algorithms in biomedical data analysis.
- This course provides the practical skills required to implement the state-of-the-art deep learning algorithms for biomedical image segmentation.
- This course teaches the application of deep generative models for biomedical image analysis.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Explain the fundamentals of state-of-the-art deep learning algorithms applied in biomedical data analysis.
- **CO2:** Apply deep learning algorithms to extract meaningful information from microscopy and radiology data.
- **CO3:** Implement state-of-the-art deep learning algorithms for biomedical data analysis.
- **CO4:** Implement Generative Adversarial Networks for data augmentation.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 1 | 1 | - | 2 | 2 | 1 |
| **CO2** | 2 | 3 | 3 | 2 | 3 | - | 2 | 3 | 1 |
| **CO3** | 2 | 3 | 3 | 3 | 2 | 1 | 2 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 3 | 2 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Introduction to ECG, EEG, MRI, and CT datasets. Hybrid deep learning models for ECG signal classification and federated transfer learning for EEG signal classification. Introduction to microscopy, diffraction limit, modern optical microscopy, super-resolution microscopy, and fluorescence microscopy. Deep learning applications in microscopy including cell counting and cell segmentation.

**Unit II**

Computer-aided probabilistic diagnosis using Bayesian Networks and deep radiology. Benchmark deep learning algorithms for biomedical image segmentation, including SwinUNet, FANet, and MedT.

**Unit III**

Generative Adversarial Networks (GANs) for synthetic data augmentation and their applications in biomedical imaging, medical data analysis, and deep learning-based healthcare systems.

**Textbooks / References**


1. *Goodfellow I, Bengio Y, Courville A, & Bengio Y, "Deep learning", Cambridge: MIT Press, 1st Edition, 2016.*
2. *Michael Nielsen, "Neural Networks and Deep Learning", Goodreads (eBook), 2013.*
3. *Bengio Y, "Learning Deep Architectures for AI, Foundations and Trends in Machine Learning", nowpublishers, 2009.*
4. *Krull, A., Buchholz, T.-O., and Jug, F. (2019). "Noise2void–learning denoising from single noisy images," in Conference on Computer Vision and Pattern Recognition (CVPR) (Long Beach, CA), 2129–2137.*
5. *Krull, A., Vic˘ar, T., Prakash, M., Lalit M. and Jug, F. (2020). "Probabilistic Noise2Void:Unsupervised Content-Aware Denoising." Frontiers in Computer Science, Vol. 2, Article 5.*
6. *https://www.frontiersin.org/articles/10.3389/fcomp.2020.00005*
7. *Weblink: https://github.com/juglab/n2v*
8. *Weblink: https://paperswithcode.com/task/ecg-classification .*
9. *Weblink: https://paperswithcode.com/task/eeg .*
10. *Weblink: https://paperswithcode.com/task/medical-image-segmentation .*
11. *Weblink: https://github.com/xinario/awesome-gan-for-medical-imaging .*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, | 30% |

| | | | |
|---|---|---|---|
| | | mini computational tasks | |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project /<br>Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational compo nent depending on course delivery | 30% |

| **26DS734** | **Deep Learning for Speech Signal Processing** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- To develop an understanding on the acoustics of speech production.
- To develop an understanding of the characteristics of speech signals.
- To analyze the time-domain and frequency domain features of speech signals.
- To develop an understanding on the deep learning based end-to-end speech processing.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Analyze the acoustics of speech signal production.
- **CO2:** Differentiate the characteristics of speech signals.
- **CO3:** Analyze the time-domain and frequency domain features of speech signals.
- **CO4:** Implement deep learning-based end-to-end speech processing pipelines for speech analysis and recognition tasks.

**CO-PO Mapping**

| **PO/PSO CO** | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PSO1** | **PSO2** | **PSO3** |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | - | - | 2 | 1 | 1 |
| **CO2** | 3 | 2 | 2 | 1 | - | - | 2 | 2 | 1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CO3** | 2 | 3 | 3 | 2 | 1 | - | 3 | 2 | 1 |
| **CO4** | 2 | 3 | 3 | 3 | 1 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Human speech production system, speech signal characteristics, classification of sound units and their properties. Short-term processing of speech, including time-domain and frequency-domain parameters, spectrograms, cepstral analysis, Mel-Frequency Cepstral Coefficients (MFCC), and linear prediction analysis.

**Unit II**

Speech recognition using Gaussian Mixture Models (GMM), Hidden Markov Models (HMM), and Deep Neural Network (DNN) models. End-to-end speech recognition systems including wav2letter, DeepSpeech, and Jasper. End-to-end speech synthesis including WaveNet and Tacotron.

**Unit III**

End-to-end speech classification, including speaker verification and speaker diarization. Other speech technology applications such as source separation, speech pathology detection, and related speech processing applications.

**Textbooks / References**


1 *L. Rabiner, Biing-Hwang Juang and B. Yegnanarayana,"Fundamentals of Speech Recognition" Pearson Education Inc.2009*
2 *Thomas F Quatieri,"Discrete Time Speech Signal Processing", Pearson Education Inc.,2004*
3 *Kamath, Uday, John Liu, and James Whitaker. Deep learning for NLP and speech recognition. Vol. 84. Cham: Springer, 2019.*
4 *Hannun, Awni, et al. "Deep speech: Scaling up end-to-end speech recognition." arXiv preprint arXiv:1412.5567 (2014).*
5 *Collobert, Ronan, Christian Puhrsch, and Gabriel Synnaeve. "Wav2letter: an end-to-end convnet-based speech recognition system." arXiv preprint arXiv:1609.03193 (2016).*
6 *Shen, Jonathan, et al. "Natural TTS synthesis by conditioning wavenet on mel spectrogram predictions." 2018 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). IEEE, 2018.*
7 *Kuchaiev, Oleksii, et al. "Mixed-precision training for NLP and speech recognition with openseq2seq." arXiv preprint arXiv:1805.10387 (2018).*
8 *Li, Jason, et al. "Jasper: An end-to-end convolutional neural acoustic model." arXiv preprint arXiv:1904.03288 (2019).*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| 26DS735 | Social Media Analytics | L-T-P-C: 2-0-3-3 |
|---|---|---|

**Course Objectives**

- To understand and apply key concepts in social media metrics.
- To monitor consumers and competitors and mine deeper consumer insights based on advanced social media data modeling techniques.
- To understand and apply key concepts in social media analytics tools and metrics.
- To understand and apply various evaluation metrics

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Apply different methods for collecting, analyzing, and exploring social media data.
- **CO2:** Develop data driven models for solving social media related problems.
- **CO3:** Analyze the social media networks to gain new insights.
- **CO4**: Assess the various evaluation metrics related to social media networks.

**CO-PO Mapping**

| PO/PSO CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 2 | 3 | 3 | 1 | 1 | - | 2 | 2 | 1 |
| **CO2** | 2 | 3 | 3 | 3 | 1 | - | 2 | 3 | 2 |
| **CO3** | 2 | 3 | 3 | 3 | 2 | 1 | 2 | 3 | 2 |
| **CO4** | 2 | 2 | 3 | 2 | 1 | 2 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Introduction to Social Media Analytics, network fundamentals and models, collecting social media data, monitoring customer engagement in social media, and fundamentals of social data analytics.

**Unit II**

Social Network Analysis (SNA) and metrics, network dynamics, phase transitions in networks, and identifying influencers in social networks.

**Unit III**

Applied social data analytics, including the application of social network models, analytics techniques, and influencer analysis for understanding and interpreting social media data.

**Textbooks / References**


1 *Szabo, G., G. Polatkan, O. Boykin and A. Chalkiopoulus," Social Media Data Mining and Analytics " Wiley, ISBN 978-1-118-82485-6.2019*
2 *Matthew A. Russell," Mining the Social Web: Data Mining Facebook, Twitter, Linkedin, Google+, Github, and More", O'Reilly Media.,2013*
3 *Finger, L. and Dutta, S. " Ask, Measure, Learn: Using Social Media Analytics to Understand and Influence Customer Behavior", O'Reilly. 2019.*
4 *David Easley and Jon Kleinberg. " Networks, Crowds, and Markets: Reasoning About a Highly Connected World", Cambridge University Press. 2010.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| 26DS736 | Deep Learning for Visual Recognition | L-T-P-C: 2-0-3-3 |
|---|---|---|

**Course Objectives**

- This course provides an understanding of state-of-the-art deep learning algorithms applied to visual recognition tasks.
- This course provides the practical skills required to implement the state-of-the-art deep learning algorithms for object detection and segmentation.
- This course provides the fundamentals of deep generative models.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Implement the fundamentals of state-of-the-art deep learning algorithms applied to visual recognition.
- **CO2:** Implement transfer learning methods for image analysis.
- **CO3:** Implement state-of-the-art deep learning algorithms for object detection.
- **CO4:** Implement state-of-the-art deep learning algorithms for image segmentation.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | 1 | 1 | - | 2 | 3 | 1 |
| **CO2** | 2 | 3 | 3 | 2 | 1 | - | 2 | 3 | 1 |
| **CO3** | 2 | 3 | 3 | 3 | 1 | 1 | 2 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 3 | 2 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Basics of Deep Neural Networks, evolution of Convolutional Neural Networks (CNNs) including Inception, Xception, ResNet, and EfficientNet. Transfer Learning and visualization of CNNs.

**Unit II**

CNNs for object detection including R-CNN, Fast R-CNN, Faster R-CNN, YOLO, and RetinaNet. U-Net for image segmentation and Vision Transformers.

**Unit III**

Introduction to deep generative models and self-supervised contrastive learning.

**Textbooks / References**


1 *Goodfellow I, Bengio Y, Courville A, & Bengio Y, "Deep learning", Cambridge: MIT Press, 1st Edition, 2016.*
2 *Michael Nielsen, "Neural Networks and Deep Learning", Goodreads (eBook), 2013.*
3 *Bengio Y, "Learning Deep Architectures for AI, Foundations and Trends in Machine Learning", now publishers, 2009.*
4 *Zeiler, Matthew D., and Rob Fergus. "Visualizing and understanding convolutional networks." In Computer Vision–ECCV 2014: 13th European Conference, Zurich, Switzerland, September 6-12, 2014, Proceedings, Part I 13, pp. 818-833. Springer International Publishing, 2014.*
5 *Dosovitskiy, Alexey, et al. "An image is worth 16x16 words: Transformers for image recognition at scale." arXiv preprint arXiv:2010.11929 (2020).*

6 *Chen, Ting, Simon Kornblith, Mohammad Norouzi, and Geoffrey Hinton. "A simple framework for contrastive learning of visual representations." In International conference on machine learning, pp. 1597-1607. PMLR, 2020.*

**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| 26DS737 | Deep Learning for Cyber Security | L-T-P-C: 2-0-3-3 |
|---|---|---|

**Course Objectives**

- To understand the basic concepts of deep learning and cyber security.
- To implement deep learning algorithms in cyber security related problems.

- To create cybersecurity tools using deep learning models.

**Course Outcomes**
After completing this course, the students will be able to,

**CO1:** Explain the fundamental concepts of deep learning and cybersecurity.
**CO2:** Apply deep learning techniques for malware analysis and detection.
**CO3:** Analyze the use of deep learning for intrusion detection and anomaly detection.
**CO4:** Implement deep learning algorithms to solve cybersecurity problems.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | 1 | 1 | - | 2 | 3 | 1 |
| **CO2** | 2 | 3 | 3 | 2 | 2 | - | 2 | 3 | 1 |
| **CO3** | 2 | 3 | 3 | 3 | 2 | 1 | 2 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 3 | 2 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**
Introduction to Cyber Security, vulnerabilities, risks, cyber threats, cyber security safeguards - access control, audit, authentication, cryptography, denial-of-service, firewalls, spam email detection, intrusion detection, intrusion prevention, malware attacks and counter measures, malicious URL detection.

**Unit II**
Trends in AI for Cyber Security, Applications of ML/DL in Cyber Security, Supervised Learning- CNN & RNN for Cyber Security, Identification of Phishing Websites using DNNs, Unsupervised Learning in Neural Networks, Auto Encoders and RBMs for Spam Filtering, Machine Learning based DDoS Detection and Mitigation.

**Unit III**
Basic deep learning concepts, Cybersecurity and Deep Learning- Intelligence through Data Integration, Cryptomodule Identification in Malwares, Deep learning for malware analysis and Intrusion detection, Transfer Learning for Cyber Security, LLMs for Cyber Security, Real world case studies on cyber threats.

**Textbooks / References**


1 *Deep Learning Applications for Cyber Security (Advanced Sciences and Technologies for Security Applications) by Mamoun Alazab, MingJian Tang, 2020.*
2 *Hands-On Machine Learning for Cybersecurity by Soma Halder, Sinan Ozdemir, 2018.*

3 *Intrusion detection and Prevention by Carl Enrolf, Eugene Schultz, Jim Mellander, McGraw Hill, 2003.*
4 *The art of software security assessment: Identifying and preventing software vulnerabilities by Dowd, Mark, John McDonald, and Justin Schuh, Pearson Education, 2006.*
5 *Data Mining and Machine learning in Cybersecurity by Sumeet Dua and Xian Du CRC Press, 2011.*

**Evaluation Pattern**

| **Assessment component** | **Internal / External** | **Suggested Assessment Methods** | **Weightage (%)** |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

**26DS738 Complex Systems in Engineering, Finance & Biology: Modelling & Analysis**
**L-T-P-C: 2-0-3-3**

**Course Objectives**

- The course will lay down the basic concepts of complex system theory required to model and analyse various physical systems
- The course will explore these concepts initially through computational experiments and then develop an understanding of the underlying concepts and theory.
- The course will help students perceive and address engineering problems using fundamental concepts from engineering, finance, and biology.
- Another goal of the course is to establish connections between the concepts of complex systems theory, mathematics and computational thinking.

**Course Outcomes**

After completing this course, the students will be able to,

**CO1:** Develop mathematical models of complex physical, biological, and engineering systems.

**CO2:** Analyze data from nonlinear systems using contemporary modeling and analytical techniques.

**CO3:** Apply complex systems theory to predict transitions and emergent behaviours in engineering, financial, and biological systems.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 2 | - | - | 3 | 1 | 2 |
| **CO2** | 2 | 3 | 3 | 2 | 1 | 1 | 3 | 2 | 2 |
| **CO3** | 2 | 3 | 2 | 3 | 2 | 1 | 3 | 2 | 3 |

**Syllabus**

**Unit I**

Definition of a complex system, complex systems in engineering, complex systems in nature and society, modelling of complex systems, introduction to dynamical system theory, standard models in dynamical systems, transitions in dynamical systems, bifurcations, maps and flows, chaos, and routes to chaos. Analysis of chaotic data from experiments, basics of time series analysis, standard models in time series analysis, nonlinear time series analysis, and phase space reconstruction.

**Unit II**

Precursors to predict transitions in complex systems, critical slowing down, precursors based on recurrence, and precursors based on multifractal formalism. Emergence of order in complex systems, transitions as pattern formation, spatial early warning signals, complex networks, network properties as early warning measures, networks in natural and engineering systems, networks in biology, and networks in finance. General design principles of complex systems including autoregulation, feedforward and feedback loops, the human cell as a prototypical complex system, and network motifs in transcription, signal transduction, and neuronal networks.

**Unit III**

Modeling complex systems with Artificial Intelligence (AI), including examples from climate science, financial modeling, systems biology, and bioinformatics. Complex evolutionary and adaptive systems, self-organizing collective systems, biological computing for complex systems, and AI in networks. Applications in remote sensing, cyber security, physiology, and finance, and the future of complex system theory.

**Textbooks / References**


1 *N. Boccora, Modelling of Complex Systems, 2nd Edition, Springer 2010.*
2 *S. Strogatz, Nonlinear Dynamics and Chaos with applications to Physics, Biology, Chemistry & Engineering, 2nd Edition, Westview Press 2014.*
3 *H. D. I. Abarbanel, Analysis of Observed Chaotic Data, Springer 1997.*
4 *R. C. Hilborn, Chaos and Nonlinear Dynamics: An Introduction for Scientists and Engineers, Oxford University Press 1994.*
5 *R. H. Shumway and D. S. Stoffer, Time Series Analysis and Its Applications, 3rd Edition, Springer 2011.*
6 *D. Sornette, Critical Phenomena in Natural Sciences, Springer 2000.*
7 *M. Cross and H. Greenside, Pattern Formation and Dynamics in Non-equilibrium Systems, Cambridge University Press 2009.*
8 *R. P. Sattoras, M. Rubi and A. D. Guilera (Eds), Statistical Mechanics of Complex Networks, Springer 2003.*
9 *Uri Alon, An Introduction to Systems Biology: Design Principles of Biological Circuits, Chapman & Hall/CRC Press, London, 2007.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |

| | | | |
|---|---|---|---|
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS739** | **High Performance Computing** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- Familiarize students with HPC architecture, parallel programming and GPU architecture.
- Educate students on writing efficient parallel and GPU programming.
- Discuss various applications of HPC computational techniques in computational science.

**Course Outcomes:**

After completing this course, the students will be able to,

**CO1:** Explain the concepts of parallel computing, including parallel architectures, programming models, and algorithms.
**CO2:** Develop parallel and CUDA programs for high-performance computing applications.
**CO3:** Analyze the performance of parallel programs using appropriate performance metrics.
**CO4:** Analyze the role of high-performance computing (HPC) and artificial intelligence (AI) in transforming data science.

**CO-PO Mapping**

| PO / PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 1 | - | - | 2 | 2 | 1 |
| **CO2** | 2 | 3 | 3 | 2 | - | - | 2 | 3 | 1 |
| **CO3** | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 3 | 2 |
| **CO4** | 3 | 3 | 3 | 3 | 2 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Introduction to High-Performance Computing (HPC), architecture for parallel computing, shared memory and distributed memory in parallel computing, parallel algorithms, performance metrics of parallel systems. Introduction to OpenMP and essentials of OpenMP programming including matrix computing, data sharing, and synchronization.

**Unit II**

Introduction to MPI and distributed memory parallel programming, communication using MPI, and domain decomposition-based parallelization of matrix solvers. Introduction to CUDA, CUDA programming, thread execution in CUDA, and matrix problems using CUDA.

**Unit III**

Applications of High-Performance Computing (HPC) in data science, including Big Data Analytics, Artificial Intelligence (AI), simulation, and modelling.

**Textbooks / References**


1. *Georg Hager and Gerhard Wellein. Introduction to High Performance Computing for Scientists and Engineers (1st ed.). CRC Press, Chapman & Hall/CRC Computational Science, India, 2010.*
2. *"High Performance Computing: Modern Systems and Practices (1st ed.)" by Thomas Sterling and Matthew Anderson, Morgan Kaufmann / Elsevier, Cambridge, 2018.*
3. *"CUDA by Example: An Introduction to General-Purpose GPU Programming (1st ed.)" by Jason Sanders and Edward Kandrot, Addison-Wesley Professional, Boston, 2010.*
4. *"Parallel Programming with MPI (1st ed.)" by Peter S. Pacheco, Morgan Kaufmann Publishers, 1997*
5. *Vipin Kumar , Ananth Grama , Anshul Gupta , George Karypis. Introduction to Parallel Computing (2nd ed.). Pearson India . 2003.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS740** | **Multiscale Modelling in Fluid Mechanics** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- Impart the understanding of important concepts of continuum fluid mechanics and related modeling and computational methods.
- Introduce various particle-based fluid models in the context of game physics and fluid animation.
- Equip with the skills and tools essential for applied computational and data driven modelling in fluid dynamics.

**Course Outcomes**

After completing this course, the students will be able to,

**CO1:** Develop working knowledge of various computational and data driven fluid models.
**CO2:** Apply knowledge of data driven and computational methods to real world fluid problems and fluid animations.
**CO3:** Contribute to the development of applied computational and data driven fluid mechanics.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 1 | - | - | 3 | 1 | 2 |
| **CO2** | 2 | 3 | 3 | 2 | 1 | - | 3 | 2 | 2 |
| **CO3** | 2 | 3 | 2 | 3 | 1 | 2 | 2 | 2 | 3 |

**Syllabus**

**Unit I**

Macroscopic fluid modelling including continuum hypothesis, Reynolds Transport Theorem, continuity equation, Navier–Stokes equation, discretization schemes, and numerical solutions to partial differential equations. Flow over a cylinder and von Kármán vortex street, Reynolds-averaged Navier–Stokes (RANS) equations, and an introduction to machine learning in fluid mechanics.

**Unit II**

Introduction to deep learning for turbulence, fluid dynamics, and flow control. Mesoscopic and microscopic fluid modelling, including particle fluid models for game physics and animation, lattice gas automata, and lattice-Boltzmann methods.

**Unit III**

Machine learning applied to particle methods of fluid modelling, including the integration of data-driven techniques with mesoscopic and microscopic fluid simulation approaches.

**Textbooks / References**


1 *Som, SK., Biswas, G. and Chakraborty, S., Introduction to Fluid Mechanics and Fluid Machines, Tata McGraw-Hill Education, 2003.*
2 *Bridson, R., Fluid simulation for computer graphics, CRC Press, Taylor and Francis, 2015.*
3 *Wolf-Gladrow DA. Lattice-gas cellular automata and lattice Boltzmann models: an introduction. Springer; 2004.*
4 *Various research publications.*

**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS741** | **Computer Vision** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- To introduce students to the state-of-the-art algorithms in the area of image analysis and object recognition
- To provide exposure to video analysis techniques for object tracking and motion estimation

- To build a strong understanding of computer vision concepts and techniques for robotic vision applications
- To enable students to apply the vision algorithms and develop applications in the domain of image analysis, robotic navigation

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Develop an understanding of detailed models of image formation.
- **CO2:** Apply techniques of image analysis through image feature extraction and object recognition.
- **CO3:** Implement fundamental algorithms for video analysis, such as object tracking and motion segmentation.
- **CO4:** Analyze image registration, camera calibration, pose estimation, and stereo vision for developing robotic vision algorithms.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 1 | - | - | 2 | 2 | 1 |
| **CO2** | 2 | 3 | 3 | 2 | 1 | - | 2 | 3 | 1 |
| **CO3** | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 3 | 2 |
| **CO4** | 3 | 3 | 3 | 3 | 2 | 1 | 3 | 3 | 2 |

**Syllabus**

**Unit I**

Introduction to Image Processing, basic mathematical concepts, image enhancement including gray-level transforms and spatial filtering, extraction of special features such as edge and corner detection, morphological processing, image transforms, Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), and frequency-domain enhancement. Image segmentation algorithms including contextual and non-contextual segmentation, texture segmentation, feature detectors and descriptors, feature matching, object recognition, face detection using the Viola–Jones algorithm, and face recognition.

**Unit II**

Modern computer vision architectures based on deep convolutional neural networks, the use of motion in segmentation, optical flow and tracking algorithms, YOLO, DeepSORT for tracking custom objects in videos, and action classification using convolutional neural networks (CNNs), Recurrent Neural Networks (RNNs), and Long Short-Term Memory (LSTM) networks.

**Unit III**

Image registration, 2D and 3D feature-based alignment, pose estimation, geometric intrinsic calibration, camera models and calibration including camera projection models, projective geometry, transformations in 2D and 3D, internal parameters, lens distortion models, and calibration methods. Geometry of multiple views including stereopsis, camera and epipolar geometry, fundamental matrix, homography, rectification, Direct Linear Transformation (DLT), RANSAC, 3D reconstruction framework, auto-calibration, and introduction to Simultaneous Localization and Mapping (SLAM).

**Textbooks / References**


1 *Deep Learning (Adaptive Computation and Machine Learning series) Ian Goodfellow, Yoshua Bengio, Aaron Courville, Francis Bach, January 2017, MIT Press*
2 *Introduction to Computer Vision and its Application, Richard Szelinski,2010*
3 *E. Trucco and A. Verri, Prentice Hall, 1998.Introductory techniques for 3D Computer Vision.*
4 *Marco Treiber, \An Introduction to Object Recognition Selected Algorithms for a Wide Variety of Applications", Springer, 2010.*
5 *Forsyth and Ponce, \Computer Vision {A Modern Approach", Second Edition, Prentice Hall, 2011.*
6 *R. C. Gonzalez, R. E. Woods, 'Digital Image Processing', 4th edition Addison-Wesley,2016.*
7 *Vision: A Computational Investigation into the Human Representation and Processing of Visual Information, by David Marr, The MIT Press, ISBN-10: 0262514621, ISBN-13: 978-0262514620.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical | 20% |

| | | | |
|---|---|---|---|
| | | problem solving and modelling | |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS742** | **Reinforcement Learning** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- Learn how to define reinforcement learning (RL) tasks and understand the core principles of RL
- Understand and work with approximate solutions, including Deep Q-Network (DQN)-based algorithms.
- Explore imitation learning tasks and their solutions.
- Recognize current advanced techniques and applications in RL

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Explain the role of reinforcement learning (RL) and its relationship with other machine learning techniques.
- **CO2:** Analyze various reinforcement learning algorithms.
- **CO3:** Formulate reinforcement learning problems and solve them using appropriate RL techniques.
- **CO4:** Implement reinforcement learning algorithms for decision-making problems.

**CO-PO Mapping**

| **PO/PSO** / **CO** | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PSO1** | **PSO2** | **PSO3** |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | - | - | 2 | 2 | 1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CO2** | 3 | 2 | 2 | 1 | - | - | 2 | 3 | 1 |
| **CO3** | 2 | 3 | 2 | 3 | 1 | - | 3 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Introduction to Reinforcement Learning and its comparison with other learning paradigms, multi-armed bandit problems, decision processes and applications, Markov Decision Processes (MDPs), cross-entropy method, approximate cross-entropy method, evolution strategies including core ideas, mathematical foundations, log-derivative trick, and duct tape. Black-box optimization and its drawbacks, dynamic programming, reward design, state-value and action-value functions, measuring policy optimality, policy evaluation and improvement, and policy and value iteration.

**Unit II**

Model-free methods, model-based versus model-free learning, Monte Carlo methods and Temporal Difference (TD) learning, Q-learning, exploration versus exploitation, Monte Carlo versus Temporal Difference methods, accounting for exploration, Expected Value SARSA, on-policy versus off-policy learning, and experience replay.

**Unit III**

Approximate value-based methods, supervised learning versus reinforcement learning, loss functions in value-based reinforcement learning, difficulties with approximate methods, Deep Q-Networks (DQN) including bird's-eye view, internals, and statistical issues, Double Q-learning, additional DQN techniques, partial observability, and Reinforcement Learning through Human Feedback (RLHF).

**Textbooks / References**


1 *Sutton and Barto, Reinforcement Learning: An Introduction, 2nd Edition. MIT Press, Cambridge, MA, 2018*
2 *Csaba Szepesvári, Algorithms for Reinforcement Learning, Morgan & Claypool. 2010.*
3 *Marco Wiering and Martijn van Otterlo, Reinforcement Learning: State-of-the-Art Adaptation, Learning, and Optimization, Springer, 2012.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment | Internal | Problem-solving assignments, quizzes | 20% |

| | | | |
|---|---|---|---|
| – Theory (CAT) | | (conceptual & numerical), short tests (open/closed book), analytical exercises | |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS743** | **Blockchain Technology** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- To understand how blockchain systems, particularly Bitcoin and Ethereum, work.
- To interact with blockchain systems securely.
- To design, build, and deploy smart contracts and distributed applications
- To integrate concepts from blockchain technology into their own projects

**Course Outcomes**

After completing this course, the students will be able to ,

- **CO1:** Explain the concepts of cryptocurrency, blockchain, and distributed ledger technologies.
- **CO2:** Analyze the applications and impact of blockchain technology across various industries.
- **CO3:** Evaluate security issues related to blockchain and cryptocurrency.

- **CO4:** Design blockchain-based solutions for real-world applications.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | 1 | - | 1 | 2 | 1 |
| **CO2** | 2 | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 1 |
| **CO3** | 2 | 3 | 2 | 2 | 2 | 1 | 2 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 3 | 2 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Introduction to blockchain including history, definition, features, types, and benefits of blockchain and Bitcoin. Consensus mechanisms, CAP theorem and blockchain, decentralization methods and routes, smart contracts and platforms. Symmetric and asymmetric cryptography, public and private keys, and the theoretical foundations of cryptography with practical examples. Introduction to financial markets and use cases of blockchain technology in the financial sector.

**Unit II**

Bitcoin, transactions, blockchain, Bitcoin payments, and technical concepts related to Bitcoin cryptocurrency. Smart contracts, definition of smart contracts, Ricardian contracts, oracles, and the theoretical aspects of smart contracts. Introduction to Ethereum, including the design and architecture of the Ethereum blockchain and various technical concepts explaining its underlying principles, features, and components.

**Unit III**

Hyperledger protocol and architecture, and case studies on alternative blockchain platforms and technologies.

**Textbooks / References**


1 *Mastering Blockchain - Distributed ledgers, decentralization and smart contracts explained by Imran Bashir, Packt Publishing Ltd, Second Edition, 2018*

2 *Mastering Bitcoin: Unlocking Digital Cryptocurrencies by Andreas Antonopoulos, O'Reilly Publishing 2014.*

3 *Blockchain Basics: A Non-Technical Introduction in 25 Steps by Daniel Drescher, Apress, First Edition, 2017.*

4 *Bitcoin and Cryptocurrency Technologies: A Comprehensive Introduction by Arvind Narayanan, Joseph Bonneau, Edward Felten, Andrew Miller, and Steven Goldfeder, Princeton University Press, 2016.*

5 *The Business Blockchain: Promise, Practice, and Application of the Next Internet Technology by Vitalik Buterin, William Mougayar, Wiley; 1st edition, 2016.*

6 *Bitcoin: A Peer-to Peer Electronic Cash System by Satoshi Nakamoto, Online 2009, https://bitcoin.org/bitcoin.pdf .*

7 *Ethereum White Paper by Vitalik Buterin, Online 2017, https://ethereum.org/en/whitepaper/.*

**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS744** | **Predictive Analytics for Internet of Things** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- The course will help students apply machine learning concepts to IoT data.
- To choose appropriate machine learning models for analyzing IoT applications.
- To integrate the deep learning techniques into predictive models.
- To visualize IoT data and identify target variables using appropriate algorithms.

**Course Outcomes**
After completing this course, the students will be able to,

**CO1:** Explain the protocols and communication models used in the Internet of Things (IoT).
**CO2:** Analyze IoT data using appropriate data analytics techniques.
**CO3:** Develop cloud-based data analytics applications using appropriate platforms.
**CO4:** Apply predictive analytics techniques to solve real-world IoT problems.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 1 | 1 | - | 1 | 2 | 1 |
| **CO2** | 2 | 3 | 2 | 2 | 1 | - | 2 | 3 | 1 |
| **CO3** | 2 | 3 | 3 | 2 | 1 | - | 2 | 3 | 1 |
| **CO4** | 2 | 3 | 3 | 3 | 2 | 1 | 3 | 3 | 2 |

**Syllabus**

**Unit I**
Introduction to the Internet of Things (IoT), definitions, frameworks, and key technologies. Challenges in IoT, key hardware and software elements, and applications including smart transportation, smart cities, smart living, smart energy, smart health, and smart learning. Real-world data representation and visualization, and an introduction to data analytics for IoT.

**Unit II**
IoT analytics, including definition, challenges, devices, connectivity protocols, and data messaging protocols such as MQTT, HTTP, CoAP, and Data Distribution Services (DDS). IoT data analytics, elastic analytics concepts, and scaling techniques for IoT systems.

**Unit III**
Cloud analytics and security, cloud platforms including Amazon Web Services (AWS), Microsoft Azure, and ThingWorx. Design of data processing for analytics, application of big data technologies for storage, visualization and dashboards, designing visual analytics for IoT data, creating dashboards, creating and visualizing alerts, exploring and visualizing data, solutions for industry-specific analysis problems, and streaming data analytics for IoT.

**Textbooks / References**


1 *Big Data Analytics for Internet of Things by Tausifa Jan Saleem, Mohammed Ahsan Chishti, 1st Edition, John Wiley & Sons, 2021.*
2 *Internet of Things: A Hands-on Approach by Vijay Madisetti and Arshdeep Bahga, Hardcover – Import, University Press (India) Private Limited, 2015.*

3 *Internet of Things: Principles and Paradigms by Vahid Dastjerdi, Rajkumar Buyya, 2016.*
4 *Analytics for Internet of Things by Andrew Minteer, Packt Publications Mumbai, 2017.*
5 *Big Data Analytics for Cloud, IoT and Cognitive Computing by Min Chen, Kai Hwang, Hardcover, John Wiley & Sons, 2017.*

**Evaluation Pattern**

| **Assessment component** | **Internal / External** | **Suggested Assessment Methods** | **Weightage (%)** |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS745** | **Cloud Computing and Security in the Cloud** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- To gain in-depth knowledge of cloud computing concepts, technologies, architectures, and applications by studying state-of-the-art issues, technologies, applications, and implementations in cloud computing.
- To expose students to frontier areas of cloud computing and information systems while providing sufficient foundations to enable further study and research.
- To learn the current security standards, protocols, and best practices for delivering cloud-based enterprise services

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Explain the fundamental concepts, architectures, and service models of cloud computing.
- **CO2:** Analyze cloud computing environments, architectures, applications, and associated vulnerabilities.
- **CO3:** Develop cloud-based applications by applying cloud storage and security principles.
- **CO4:** Evaluate the performance, strengths, and limitations of cloud security algorithms.

**CO-PO Mapping**

| PO/PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | - | - | 1 | 2 | 1 |
| **CO2** | 2 | 3 | 2 | 2 | 1 | - | 2 | 2 | 1 |
| **CO3** | 2 | 3 | 3 | 2 | 2 | 1 | 2 | 3 | 2 |
| **CO4** | 2 | 3 | 2 | 2 | 2 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Introduction to cloud computing, evolution of cloud computing, definition of cloud computing, SPI framework, service delivery models, deployment models, key drivers for adopting cloud computing, and barriers to cloud computing adoption. Modular arithmetic background, concepts of security, assessment of system security, information-theoretic security versus computational security, data security and storage in the cloud, data dispersal techniques, and high-availability and integrity layers for cloud storage.

**Unit II**

Encryption and key management in the cloud, cloud forensics, data location and availability, data security tools and techniques for the cloud, data distribution and information dispersal

techniques, data encryption and decryption methodologies and algorithms for client-server setups such as SSL and IPSec, and an introduction to homomorphic encryption.

**Unit III**

Approximate string searching over encrypted data stored in the cloud, trustworthy cloud infrastructures, secure computations, and cloud-related regulatory and compliance issues.

**Textbooks / References**


1 *Zeal Vors, "Enterprise Cloud Security and Governance: Efficiently set data protection and privacy principles", First Edition, Packt Publishing, 2017.*
2 *Tim Mather, S. Kumaraswamy and S.Latif, "Cloud Security and Privacy: An Enterprise Perspective on Risks and compliance", O'Reilly Media, 2009*
3 *William Stallings, "Cryptography and Network Security: Principles and Practice, Fifth Edition, Prentice Hall, 2011.*
4 *William Stallings, Lawrie Brown, "Computer Security: Principles and Practice", Pearson, 2012.*
5 *Menezes. A, Oorschot. P, and Vanstone. S, Handbook of Applied Cryptography, CRC Press, 1996*
6 *B. Schneier, "Applied Cryptography: Protocols, Algorithms, and source Code in C", Second Edition, Jhon Wiley and Sons, 1996.*
7 *John Sammons, "The Basics of Digital Forensics: The Primer for Getting Started in Digital Forensics", second edition, Syngress (Imprint of Elsevier), 2014.*
8 *Terrence Lillard, "Digital Forensics for Network, Internet, and Cloud Computing, Elsevier, 2010.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |

| | | | |
|---|---|---|---|
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS746** | **Financial Data Analytics** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- The course aims to develop a deep understanding and visualization of various types of financial data, including market data and economic indicators.
- The course provides advanced analytical skills for processing and analyzing financial data. It covers a range of techniques, including data wrangling, exploratory data analysis (EDA), time series analysis, and predictive modelling.
- The course introduces students to concepts and methodologies for risk management and portfolio optimization.
- The course provides hands-on experience with industry-standard financial analytics tools and platforms.

**Course Outcomes**

After completing this course, the students will be able to,

- **CO1:** Explain the fundamental characteristics of financial time-series data.
- **CO2:** Analyze financial data using statistical and computational modeling techniques.
- **CO3:** Evaluate financial risk across different asset classes using quantitative methods.
- **CO4:** Implement analytical finance solutions using R or Python.

**CO-PO Mapping**

| PO / PSO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|

| CO | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | - | - | 2 | 1 | 1 |
| **CO2** | 2 | 3 | 3 | 2 | 1 | 1 | 3 | 2 | 2 |
| **CO3** | 2 | 3 | 2 | 3 | 2 | 1 | 3 | 2 | 2 |
| **CO4** | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Introduction to financial time series and their characteristics, exploratory data analysis, linear time series analysis including autoregressive (AR), moving average (MA), autoregressive integrated moving average (ARIMA), unit-root non-stationarity, and seasonality models. Conditional heteroscedastic models and volatility modeling including ARCH and GARCH models, nonlinear models and their applications including TAR and STAR models, and high-frequency data analysis and market microstructure including nonsynchronous trading, bid-ask spread, models for price changes, and duration models.

**Unit II**

Derivative pricing and continuous-time models including the Black–Scholes model. Asset portfolio models including basics of portfolio construction, Markowitz theorem, Capital Asset Pricing Model (CAPM), diversification, and portfolio optimization. Measuring and modeling risk including extreme value theory, quantile estimation, and Value at Risk (VaR).

**Unit III**

Modeling credit risk including corporate liabilities as contingent claims, endogenous default boundaries and optimal capital structure, intensity modeling, rating-based term-structure models, credit risk and interest-rate swaps, and modeling dependent defaults. Derivative pricing using continuous-time models including the Black–Scholes model, and multivariate time series analysis using Vector Autoregressive (VAR) models.

**Textbooks / References**


1. *Analysis of Financial Time Series (Wiley Series in Probability and Statistics) Ruey Tsay, 2010.*
2. *Time series analysis and its applications. Shumway and Stoffer, 3rd Edition, Springer, 2011*
3. *Advances in financial machine learning. Marcos Lopez de Prado, 1st Edition, John Wiley & Sons, 2018.*
4. *Hilpisch, Yves. Python for Finance: Analyze big financial data. " O'Reilly Media, Inc.", 2014.*
5. *Ruey S. Tsay (2012), "An Introduction to Analysis of Financial Data with R" , Wiley, ISBN: 978-0-470-89081-3*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS747** | **Materials Informatics** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- The course aims to introduce students to the effective management and organization of materials data using tools and techniques from the field of informatics.
- This course will also familiarize students with the application of machine and deep learning algorithms to predict materials properties, design new materials, and optimize material performance.

- This course will provide students with hands-on experience in AI/ML-driven materials design and discovery.

**Course Outcomes:**

After completing this course, the students will be able to,

- **CO1**: Query available materials databases for optimal material design.
- **CO2**: Apply machine learning algorithms for materials design and discovery.
- **CO3**: Apply Bayesian approaches to accelerate materials design and discovery.
- **CO4**: Apply natural language processing techniques in materials science for data mining.

**CO-PO Mapping**

| PO / PSO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO** | | | | | | | | | |
| **CO1** | 2 | 3 | 2 | 1 | 1 | - | 2 | 2 | 1 |
| **CO2** | 3 | 3 | 3 | 2 | 1 | - | 2 | 3 | 2 |
| **CO3** | 2 | 3 | 3 | 3 | 1 | 1 | 3 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 3 | 2 |

**Syllabus**

**Unit I**

Introduction to materials informatics, historical paradigm of materials discovery, understanding property, structure, and process spaces, and the role of data science in the materials knowledge system. Materials databases and featurization including string and graph representations, familiarization with the Materials Project API, querying databases, composition-based feature vectors, structure-based feature vectors, handling molecular descriptors, and crystal graph networks.

**Unit II**

Machine learning for materials science, including simple linear and nonlinear models, training, testing, validation, performance metrics, ensemble models, support vector machines, and artificial neural networks. Accelerating materials design and discovery through frameworks for optimal design of material systems, Bayesian inference, Gaussian processes, Bayesian optimization, and data-intensive investigations including uncertainty quantification, sensitivity analysis, and multi-objective optimization.

**Unit III**

Natural Language Processing (NLP) for materials science, including design of materials embeddings, Mat2Vec, chemical similarity-based embeddings, and named entity recognition (NER) in materials science. Active learning methods and leveraging first-principles density functional theory (DFT) computations for materials discovery and design.

**Textbooks / References**


1 *Olexandr Isayev, Alexander Tropsha, Stefano Curtarolo, Materials Informatics, Wiley.*
2 *Murdock, R.J., Kauwe, S.K., Wang, A.Y.T. and Sparks, T.D., 2020. "Is domain knowledge necessary for machine learning materials properties?" Integrating Materials and Manufacturing Innovation, 9, pp.221-227.*
3 *Sayeed, H.M., Baird, S.G. and Sparks, T.D., 2023. Structure feature vectors derived from Robocrystallographer text descriptions of crystal structures using word embeddings.*
4 *Anoop Krishnan N. M., Kodamana H., Bhattoo R., "Machine Learning for Materials Discovery," 1st Edition, Springer, 2024.*
5 *Roman Garnett, "Bayesian Optimization", Cambridge University Press, 2023.*
6 *Hargreaves, C.J., Dyer, M.S., Gaultois, M.W., Kurlin, V.A. and Rosseinsky, M.J., 2020. The earth mover's distance as a metric for the space of inorganic compositions. Chemistry of Materials, 32(24), pp.10610-10620.*
7 *Tshitoyan, V., Dagdelen, J., Weston, L., Dunn, A., Rong, Z., Kononova, O., Persson, K.A., Ceder, G. and Jain, A., 2019. Unsupervised word embeddings capture latent knowledge from materials science literature. Nature, 571(7763), pp.95-98.*


**Evaluation Pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / | 30% |

| | | | |
|---|---|---|---|
| | | Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational compo nent depending on course delivery | |

| **26DS748** | **Integration of data science and system biology** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objective**

- The course will introduce the application of data science to systems biology, an emerging research field in biosciences.
- The course will explore the concept of Markov modelling of stochastic processes, mathematical formulation of the stochastic dynamics along with the simulation techniques of the stochastic processes.
- The course will provide theoretical techniques to handle the big data obtained from the stochastic single molecular experiments and imaging processes.

**Course Outcome**

After completing this course, the students will be able to,

- **CO1:** Analyze large-scale random data generated by stochastic processes in systems biology.
- **CO2:** Formulate stochastic equations of motion, including the Langevin equation and the master equation, to model stochastic dynamics.
- **CO3:** Apply simulation techniques for stochastic processes and network dynamics, including kinetic Monte Carlo and Langevin dynamics methods.
- **CO4:** Analyze stochastic dynamics using concepts from nonequilibrium statistical mechanics to solve problems in physics, chemistry, biology, and economics.

**CO-PO Mapping**

| **PO/PSO** | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PSO1** | **PSO2** | **PSO3** |
|---|---|---|---|---|---|---|---|---|---|
| **CO** | | | | | | | | | |
| **CO1** | 3 | 2 | 2 | 1 | 1 | - | 3 | 1 | 2 |
| **CO2** | 3 | 3 | 2 | 2 | - | - | 3 | 1 | 2 |
| **CO3** | 2 | 3 | 3 | 2 | 1 | 1 | 3 | 2 | 2 |
| **CO4** | 2 | 3 | 2 | 3 | 2 | 1 | 3 | 2 | 3 |

**Syllabus**

**Unit I**

Systems biology: its necessity and applications, concept of networks in systems biology, inter- and intra-cellular networks, stochastic time evolution of cellular networks, obtaining big data from cellular network dynamics and its importance using gene-expression networks as a model, mathematical modelling of cellular network dynamics, concepts of continuous and discrete state spaces, and understanding of Markov processes and transition probabilities. General design principles of biological networks including autoregulation, feedforward loops, and feedback loops, and network motifs in transcription, signal transduction, and neuronal networks.

**Unit II**

Stochastic dynamics in continuous space, Wiener and Ornstein–Uhlenbeck processes, understanding drift and diffusion terms, construction of the Langevin equation, introduction to stochastic integrals including Ito and Stratonovich descriptions, Kolmogorov forward and backward differential equations, introduction to Langevin dynamics simulation, stochastic dynamics in discrete space, formulation of the master equation, and introduction to Kinetic Monte Carlo simulation.

**Unit III**

Formulation of cell phenotypic transitions using dynamical systems theory, procedures for extracting dynamical information from snapshot data and live-cell time-series data, and challenges and perspectives in the analysis and modelling of cellular dynamics.

**Textbooks / References**


1. *An Introduction to Systems Biology: Design Principles of Biological Circuits, Uri Alon, (Chapman & Hall/CRC Mathematical and Computational Biology), 2007.*
2. *Data Mining for System Biology, Methods, and Protocols, Hiroshi Mamitsuka, Chapman & Hall/CRC Mathematical and Computational Biology, 2018.*
3. *Big Data Mining, Network Modelling, and Genome-Wide Data Identification, Bor-Sen Chen, Cheng-Wei Li, Elsevier, 2016.*
4. *Stochastic processes in physics and Chemistry, N. G. Van Kampen, 3rd edition, Science Direct, 2007.*
5. *Handbook of stochastic methods for physics, chemistry and natural sciences, C. W. Gardiner, 2nd edition, Springer, 1985.*
6. *The Fokker-Planck equation methods of solution and application, H. Risken, 2nd edition, Springer, 1996.*


**Evaluation pattern**

| Assessment component | Internal / External | Suggested Assessment Methods | Weightage (%) |
|---|---|---|---|
| Continuous Assessment | Internal | Problem-solving assignments, quizzes | 20% |

| | | | |
|---|---|---|---|
| – Theory (CAT) | | (conceptual & numerical), short tests (open/closed book), analytical exercises | |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

| **26DS749** | **Introduction to Graph Theory** | **L-T-P-C: 2-0-3-3** |
|---|---|---|

**Course Objectives**

- To achieve proficiency in fundamental graph theory concepts and definitions and differentiate among various types of graphs
- To explore key graph theory theorems, algorithms, and their applications.
- To gain exposure to advanced topics and recent developments in graph theory, including random graphs, spectral graph theory, and applications in computer science and biology.

**Course Outcomes:**

After completing this course, the students will be able to,

- **CO1:** Explain the basic concepts of graph theory.

- **CO2:** Model real-world problems using graph theory.
- **CO3:** Apply different graph theory algorithms to solve network-related problems across diverse fields.
- **CO4:** Develop an understanding of graph mining, graph machine learning, and graph neural networks.

**CO-PO Mapping**

| PO / PSO CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PSO1 | PSO2 | PSO3 |
|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | - | - | 2 | 1 | 1 |
| **CO2** | 2 | 3 | 2 | 2 | 1 | - | 2 | 2 | 1 |
| **CO3** | 2 | 3 | 3 | 3 | 2 | 1 | 2 | 3 | 2 |
| **CO4** | 2 | 3 | 3 | 3 | 1 | 1 | 2 | 3 | 3 |

**Syllabus**

**Unit I**

Fundamental graph concepts including definitions and examples of different graph types and subgraphs, adjacency matrices, isomorphism, decompositions, Ramsey numbers, paths, cycles, trails, vertex degrees, counting, directed graphs, weak connectivity, connectivity, and strong components. Trees including cut edges and bonds, cut vertices, Cayley's formula, spanning trees, Kruskal's theorem, and Dijkstra's theorem. Connectivity concepts including walks, trails, paths, connectedness and components, blocks, 2-connected and 3-connected graphs, Eulerian graphs, Euler tours, Hamilton cycles, and Menger's theorem.

**Unit II**

Matching and covering, including bipartite matching, vertex cover, edge cover, independent sets, M-alternating paths, and Hall's theorem. Graph colorings including vertex coloring, Brooks' theorem, edge coloring, Vizing's theorem, girth and chromatic numbers, list coloring, chromatic index, chromatic polynomials, and k-critical graphs. Planarity including plane and planar graphs, 5-coloring of planar graphs, and Kuratowski's theorem. Special classes of graphs including perfect graphs, interval graphs, chordal graphs, boxicity, sphericity, and the 4-color conjecture.

**Unit III**

Graph centrality measures and spectral graph theory, including the analysis of eigenvalues and eigenvectors of adjacency and Laplacian matrices. Network flow concepts including maximum-flow minimum-cut theorem, circulations, tensions, Ford–Fulkerson labeling algorithm, and flow integrality. GraphAI, including an introduction to graph mining, graph neural networks, and graph machine learning.

**Textbooks / References**

1 *Reinhard Diestel, "Graph Theory", Springer (2010)*

2 *Douglas B. West, "Introduction to Graph Theory", Prentice Hall (2001)*
3 *A. Bondy and U. S. R. Murty, "Graph Theory", Springer (2008)*
4 *B. Bollabas, "Modern Graph Theory", Springer (1998)*
5 *M. E. J. Newman, Networks: An Introduction, Oxford University Press, Oxford, 2010.*

**Evaluation Pattern**

| **Assessment component** | **Internal / External** | **Suggested Assessment Methods** | **Weightage (%)** |
|---|---|---|---|
| Continuous Assessment – Theory (CAT) | Internal | Problem-solving assignments, quizzes (conceptual & numerical), short tests (open/closed book), analytical exercises | 20% |
| Continuous Assessment – Lab (CAL) | Internal | Computational exercises using Python/MATLAB, mini computational tasks | 30% |
| Mid-Term Examination | Internal | Written examination focusing on analytical problem solving and modelling | 20% |
| End Semester Assessment | External | Term Project / Hybrid mode: Written exam + problem-solving/modelling questions; may include a small computational component depending on course delivery | 30% |

**25AVP501** **Mastery Over Mind (MAOM)** **1-0-2 2**

Course Outcomes

**CO01**: Relate to the causes of stress in one's life.

**CO02**: Experiment with a range of relaxation techniques

**CO03**: Model a meditative approach to work, study, and life.

**CO04**: Develop appropriate practice of MA-OM technique that is effective in one's life

**CO05:** Inculcate a higher level of awareness and focus.

**CO06:** Evaluate the impact of a meditation technique

**1. Course Overview**

Master Over the Mind (MAOM) is an Amrita initiative to implement schemes and organise university-wide programs to enhance health and wellbeing of all faculty, staff, and students (UN SDG -3). This program as part of our efforts for sustainable stress reduction gives an introduction to immediate and long-term benefits and equips every attendee to manage stressful emotions and anxiety facilitating inner peace and harmony.

With a meditation technique offered by Amrita Chancellor and world-renowned humanitarian and spiritual leader, Sri Mata Amritanandamayi Devi (Amma), this course has been planned to be offered to all students of all campuses of AMRITA, starting off with all first years, wherein one hour per week is completely dedicated for guided practical meditation session and one hour on the theory aspects of MAOM. The theory section comprises lecture hours within a structured syllabus and will include invited guest lecture series from eminent personalities from diverse fields of excellence. This course will enhance the understanding of experiential learning based on university's mission: "Education for Life along with Education for Living", and is aimed to allow learners to realize and rediscover the infinite potential of one's true Being and the fulfilment of life's goals.

**2. Course Syllabus**

**Unit 1 (4 hours)**

Causes of Stress: The problem of not being relaxed. Need for meditation -basics of stress management at home and workplace. Traditions and Culture. Principles of meditation– promote a sense of control and autonomy in the Universal Human Value System. Different stages of Meditation. Various Meditation Models. Various practices of Meditation techniques in different schools of philosophy and Indian Knowledge System.

**Unit 2 (4 hours)**

Improving work and study performance. Meditation in daily life. Cultivating compassion and good mental health with an attitude of openness and acceptance. Research and Science of Meditation: Significance of practising meditation and perspectives from diverse fields like science, medicine, technology. philosophy, culture, arts, management, sports, economics, healthcare, environment etc. The role of meditation for stress and anxiety reduction in one's life with insights based on recent cutting-edge technology. The effect of practicing meditation for the wholesome wellbeing of an individual.

**Unit 3 (4 hours)**

Communications: principles of conscious communication. Relationships and empathy: meditative approach in managing and maintaining better relationships in life during the interactions in the world, role of MAOM in developing compassion, empathy and responsibility, instilling interest, and orientation to humanitarian projects as a key to harness intelligence and compassion in youth. Methodologies to evaluate effective awareness and relaxation gained from meditation. Evaluating the global transformation through meditation by instilling human values which leads to service learning and compassion driven research.

**TEXT BOOKS:**

1.Mata Amritanandamayi Devi, "Cultivating Strength and vitality," published by Mata Amritanandamayi Math, Dec 2019

2.Swami Amritaswarupananda Puri ,"The Color of Rainbow " published by MAM, Amritapuri.

**REFERENCES:**

1.Craig Groeschel, "Winning the War in Your Mind: Change Your Thinking, Change Your Life" Zondervan Publishers, February 2019

2.R Nagarathna et al, "New Perspectives in Stress Management "Swami Vivekananda Yoga Prakashana publications, Jan 1986

3. Swami Amritaswarupananda Puri "Awaken Children Vol 1, 5 and 7 - Dialogues with Amma on Meditation", August 2019

4. Swami Amritaswarupananda Puri "From Amma's Heart - Amma's answer to questions raised during world tours" March 2018

5. Secret of Inner Peace- Swami Ramakrishnananda Puri, Amrita Books, Jan 2018.

6. Mata Amritanandamayi Devi "Compassion :The only way to Peace:Paris Speech", MA Center, April 2016.

7. Mata Amritanandamayi Devi "Understanding and collaboration between Religions", MA Center, April 2016.

8. Mata Amritanandamayi Devi "Awakening of Universal Motherhood: Geneva Speech" M A center, April 2016.

| **26CUL500** | **INTEGRATED AMRITA MEDITATION TECHNIQUE** | **L-T-P-C 0-0-2-1** |
|---|---|---|

**A. Nature of Course:** Lab/Practical

**B. Course Description:**

The course introduces students to the Integrated Amrita Meditation Technique (IAM 20), a structured practice that combines yogic stretches, regulated breathing (pranayama), and guided meditation. The course integrates both theoretical understanding and experiential practice to enhance emotional balance, stress resilience, concentration, and overall holistic development.

Aligned with United Nations Sustainable Development Goal 3 (SDG 3): Good Health and Well-Being, the course promotes preventive mental health care, emotional well-being, and sustainable lifestyle practices among students. By fostering inner stability, self-awareness, and self-regulation, the programme supports academic excellence and contributes to the development of healthy individuals and communities.

The course is expected to improve student well-being, enhance academic focus and cognitive clarity, reduce stress-related indicators, and promote compassionate and emotionally supportive culture.

**C. Course Objectives:**

- To promote overall health and well-being of students.
- To train students in the structured practice of IAM 20.
- To develop emotional regulation and stress management skills.
- To encourage reflective awareness and compassionate living.

**D. Course Outcomes:**

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

| CO | Course Outcomes | Knowledge Level (Bloom's Taxonomy) |
|---|---|---|
| **CO1** | Explain principles and components of IAM 20 | Understand (L2) |
| **CO2** | Demonstrate and correct meditation practice independently | Apply (L3) |
| **CO3** | Analyze personal stress patterns using meditation insights | Analyse (L4) |
| **CO4** | Evaluate personal growth through daily practice | Evaluate (L5) |

**E. CO-PO Mapping: [affinity: 3 – high; 2- moderate; 1- slightly]**

| CO's | Program Outcomes (PO's) | | | | | | | | | | | Program Specific Outcomes (PSF's) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO10 | PO11 | PSO 1 | PSO 2 | PSO 3 |
| CO 1 | - | - | - | - | - | 1 | - | 2 | - | - | 1 | - | - | - |
| CO 2 | - | - | - | - | - | 2 | 2 | 1 | 1 | - | 1 | - | - | - |
| CO 3 | - | - | - | - | - | 1 | 1 | 2 | - | - | 1 | - | - | - |
| CO 4 | - | - | - | - | - | 1 | 1 | 1 | 1 | - | 1 | - | - | - |

## F. Syllabus

**Unit 1: Foundations of Meditation (CO1)**

- Meaning and purpose of meditation
- Demonstration and supervised training
- Overview of structure of IAM
- Guidance for safe and effective practice
- Importance of mental health

**Unit 2: Theoretical Foundations (CO2)**

- Structure and components of IAM: yogic stretches, regulated breathing, and guided meditation
- Breath–mind connection
- Integration of IAM practice into daily routine and academic life
- Application of IAM for stress management, concentration, and holistic student development

**Unit 3: IAM Practical Training (CO3)**

- Preparatory stretches
- Pranayama components
- Guided meditation sequence
- Corrections and common challenges

**Unit 4: Integration and Transformation (CO4)**

- Building daily discipline
- Research evidence in higher education

- Compassion and mindful communication

**G. Evaluation Pattern:**

| Assessment | Internal (60) | External (40) |
|---|---|---|
| Attendance | 20 Marks | |
| Class Participation | 20 Marks | |
| Activity | 20 Marks | |
| | | |
| Practical Demonstration | | 30 Marks |
| Viva | | 10 Marks |

**CIR Course – PG – Paper I**

| Sem: 1 | 26CDS101 Career Development Skills I | L-T-P-C: 0 0 3 P/F |
|---|---|---|

**Pre-requisite:**

An open mind and the urge for self-development, basic English language skills and knowledge of high school level arithmetic.

**Course Objectives:**

- To strengthen professional skills for academic and research environments.
- To enhance presentation skills for seminars, reviews, and academic discussions.
- To guide students in effective goal setting and time management for postgraduate studies.
- Support them in developing their problem solving and reasoning skills
- Inspire students to enhance their diction, grammar, verbal reasoning and communication skills

**Course Outcomes:**

**CO1: Soft Skills** - To develop a positive mindset, communicate professionally, manage time effectively, set personal goals and achieve them.
**CO2: Soft Skills** - To make formal and informal presentations with self-confidence.
**CO3: Aptitude** - To analyze, understand and employ the most suitable methods to solve questions on arithmetic and algebra.
**CO4: Aptitude** - To analyze, understand and apply suitable techniques to solve questions in data analysis.
**C05: Verbal** - To infer the meaning of words and use them in the right context. To have a clearer understanding of the nuances of English grammar and become capable of applying them effectively.

**C06: Verbal** - To identify the relationship between words using reasoning skills. To understand and analyze arguments and use verbal reasoning skills to arrive at conclusions and communicate ideas/perspectives convincingly.

**CO-PO Mapping - MTech**

| PO / CO | PO1 | PO2 | PO3 |
|---|---|---|---|
| **CO1** | 2 | 1 | - |
| **CO2** | 2 | 1 | - |
| **CO3** | 2 | 1 | - |
| **CO4** | 2 | 1 | - |
| **CO5** | 1 | 2 | - |
| **CO6** | 2 | 2 | - |

**CO-PO Mapping** - PG **ASAS**

| PO / CO | PO1 | PO2 |
|---|---|---|
| **CO1** | 2 | 1 |
| **CO2** | 2 | 1 |
| **CO3** | 2 | 1 |
| **CO4** | 2 | 1 |
| **CO5** | 1 | 2 |
| **CO6** | 2 | 2 |

**Syllabus**

**Soft Skills**

**Introduction**: Campus to corporate transition based on the expectations of the corporate

**Communication and listening skills**: Professional & Academic Communication Skills, Interpersonal Communication in Teams, Cross-cultural & Global Communication, Netiquette in Corporate Settings, Communicating in Hybrid & Remote Teams

**Assertiveness skills**: Necessity of being Assertive, Passive Aggression & Aggressiveness, Assertive & Non-assertive differences, Dealing with demands, criticism & Compliments, Assertive Techniques

**Presentation skills**: Adult learning principles, Preparation, planning, practice delivery, Principles of Effective Technical Presentations, Verbal & Non-verbal Communication in Presentations, Effective Slide Design, Using AI & Digital Tools for Presentations

**Presentations by the students**

**Perception**: Locus of control, Bridging Self & Social perception, Attribution theories, Importance of Perspective Taking, Impression management

**Goal setting & Time management**: Aligning Personal, Academic & Career Goals, SMART Goals, SWOT Analysis, Time Management Strategies, Prioritization Techniques & Planning Tools, Avoiding Procrastination & Distractions

**Verbal**

**Vocabulary**: Familiarize students with the etymology of words, help them realize the relevance of word analysis and enable them to answer vocabulary based MCQ questions through practice in etymology, synonyms, antonyms, commonly confused words, and contextual usage.

**Grammar**: Train students to understand the nuances of English Grammar and thereby enable them to spot grammatical errors in sentences.

**Commented [M[1]:** We have introduced
-Netiquette in corporate setting, effective communication strategies in Hybrid & Remote teams to cater the requirement of growing virtual work culture and recruitment process.
-Dealing with demands, criticism & compliments in Assertive Techniques to handle difficult conversations in effective way.
-Using AI & Digital Tools for Presentations -to expose them in ethical way of implementing it
-Importance of Perspective Taking in perceptions to highlight the importance of unbiased approach.

**Reasoning**: Stress the importance of understanding the relationship between words through analogy questions. Emphasize the importance of avoiding the gap (assumption) in arguments/ statements/ communication.

**Oral Communication Skills:** Improve the professional spoken communication by introducing corporate register, workplace expressions, and structured group activities such as debates and panel discussions.

**Commented [A(2]:** The verbal component of the course is structured into two integrated parts: **Verbal Ability** and **Communication Skills**. The **Verbal Ability** component focuses on strengthening students' vocabulary, grammar, and reasoning skills by equipping PG students with effective strategies for word analysis, grammatical accuracy, and logical relationships, thereby enabling them to perform competently in placement tests and other competitive examinations. The **Communication Skills** component emphasizes the application of these language skills in professional contexts, helping students develop confidence, clarity, and appropriateness in spoken communication through exposure to corporate register and structured group activities such as debates and panel discussions.

**Aptitude**

**Numbers -** Power Cycles, Divisibility, and HCF & LCM, **Percentages -** Profit, Loss & Discount, and Simple & Compound Interest, **Ratio, Proportion & Variation -** Alligations, Mixtures, and Partnership Problems, **Averages, Time and Work -** Pipes & Cistern, and Work Equivalence, **Time, Speed and Distance -** Boats & Streams, Races and Circular tracks, **Statistics -** Mean, Median, Mode, Standard Deviation and Quartile Deviation, **Data Interpretation -** Tables, Bar Diagrams, Line Graphs, Pie Charts, Caselets and Mixed Varieties, **Equations –** Linear and Quadratic Equations, **Logarithms, Inequalities, Puzzles -** Optimization Puzzles, Fermi Problems, Game-Based Puzzles, Sudoku, Anagrams, Futoshiki and Rebus Puzzles, **Speed Mathematics**, **Shortcuts.**

**References**

**Soft Skills**


1. Student's Guide For Career Planning, CIR, 2018
2. Andrew J DuRbin , "Applied Psychology: Individual and organizational effectiveness", Pearson- Merril Prentice Hall, 2004
3. Michael G Aamodt, "An Applied Approach, 6th edition", Wadsworth Cengage Learning, 2010
4. Robert Bolton, Dorothy Grover Bolton, "People Style at Work..and Beyond: Making Bad Relationships Good and Good", Ridge Associates Inc., 2009
5. John Hayes "Interpersonal skills at work", Routledge, 2003
6. Nord, W. R., Brief, A. P., Atieh, J. M., & Doherty, E. M., "Meanings of occupational work: A collection of essays (pp. 21- 64)", Lexington, MA: Lexington Books, 1990
7. Mark J Martinko, "Attribution theory: an organizational perspective", St. Lucie, 1995
8. Miles Hewstone,"Attribution Theory: Social and Functional Extensions", Blackwell, 1983
9. Stephen Covey, "The habits of highly effective people", Free press Revised edition, 2004
10. Kenneth H Blanchard ,"The 25 Best Time Management Tools & Techniques: How to Get More Done Without Driving Yourself Crazy" , Peak Performance Press, 1st edition 2005
11. Kenneth H. Blanchard and Spencer Johnson, "The One Minute Manager", William Morrow, 1984


**Verbal**


1. Verbal Skills Workbook (PG), CIR
2. Erica Meltzer, "The Ultimate Guide to SAT Grammar"

3. Green, Sharon, and Ira K. Wolf, “Barron's New GRE”, Barron's Educational Series, 2011
4. Jeff Kolby, Scott Thornburg & Kathleen Pierce, “Nova’s GRE Prep Course”
5. Kaplan, “Kaplan New GRE Premier”, 2011-2012
6. Kaplan’s GRE Comprehensive Programme
7. Lewis Norman, “Word Power Made Easy”, Goyal Publishers, Reprint edition, 1 June 2011
8. Manhattan Prep, “GRE Verbal Strategies Effective Strategies Practice from 99th Percentile Instructors”
9. Pearson- “A Complete Manual for CAT”, 2013
10. R.S. Aggarwal, “A Modern Approach to Verbal Reasoning”
11. S. Upendran, “Know Your English”, Universities Press (India) Limited, 2015
12. Sharon Weiner Green, Ira K. Wolf, “Barron's New GRE, 19th edition (Barron's GRE)”, 2019
13. Wren & Martin, “English Grammar & Composition”
14. www.bbc.co.uk/learningenglish
15. www.cambridgeenglish.org
16. www.englishforeveryone.org
17. www.merriam-webster.com

**Aptitude**

1. Arun Sharma, “How to Prepare for Quantitative Aptitude for the CAT Common Admission Test”, Tata Mc Graw Hills, 5th Edition , 2012
2. Arun Sharma, “How to Prepare for Logical Reasoning for the CAT Common Admission Test”, Tata Mc Graw Hills, 2nd Edition, 2014
3. Arun Sharma, “How to Prepare for Data Interpretation for the CAT Common Admission Test”, Tata Mc Graw Hills, 3nd Edition, 2015
4. R.S. Aggarwal, “Quantitative Aptitude For Competitive Examinations”, S. Chand Publishing, 2015
5. R.S. Aggarwal, “A Modern Approach To Verbal & Non-Verbal Reasoning”, S. Chand Publishing, Revised -2015
6. Sarvesh Verma, “Quantitative Aptitude-Quantum CAT” , Arihant Publications, 2016
7. www.mbatious.com
8. www.campusgate.co.in
9. www.careerbless.com

**Evaluation Pattern**

| Assessment | Internal | External |
|---|---|---|
| Continuous Assessment (CA)* – Soft Skills | 30 | - |
| Continuous Assessment (CA)* – Aptitude | 10 | 25 |
| Continuous Assessment (CA)* – Verbal | 10 | 25 |
| Total | 50 | 50 |
| **Pass / Fail** | | |

*CA - Can be **presentations, speaking activities and tests.**

**CIR Course – PG – Paper II**

| Sem: 2 | 26CDS111 Career Development Skills II | L-T-P-C: 0 0 3 1 |
|---|---|---|

**Pre-requisite:**

Willingness to learn, team spirit, foundational proficiency in English language and communication and knowledge of high school level arithmetic.

**Course Objectives:**

- To equip students with conflict management strategies for effective teamwork and collaboration.
- To prepare students for recruitment processes through interview etiquette, group discussions and professional conduct.
- Help students to sharpen their problem solving and reasoning skills
- Empower students to communicate effectively by using the correct diction, grammar, comprehension and verbal reasoning skills

**Course Outcomes:**

**CO1: Soft Skills -** To demonstrate good interpersonal skills, solve problems and effectively participate in group discussions.
**CO2: Soft Skills -** To write technical resumes and perform effectively in interviews.
**CO3: Aptitude -** To identify, investigate and arrive at appropriate strategies to solve questions in geometry, probability, permutations & combinations, and statistics by managing time effectively.
**CO4: Aptitude -** To investigate, understand and use appropriate techniques to solve questions in logical reasoning and data analysis by managing time effectively.
**C05: Verbal -** To be able to use diction that is more refined and appropriate and to be competent in knowledge of grammar to correct and improve sentences
**C06: Verbal** - To be able to examine, interpret and investigate passages and to be able to generate ideas, structure them logically and express them in spoken or written style that is comprehensible to the audience/recipient.

**CO-PO Mapping - MTech**

| PO / CO | PO1 | PO2 | PO3 |
|---|---|---|---|
| **CO1** | 2 | 1 | - |
| **CO2** | 2 | 1 | - |
| **CO3** | 2 | 1 | - |
| **CO4** | 2 | 1 | - |
| **CO5** | 1 | 2 | - |
| **CO6** | 2 | 2 | - |

**CO-PO Mapping** - PG **ASAS**

| PO / CO | PO1 | PO2 |
|---|---|---|
| **CO1** | 2 | 1 |
| **CO2** | 2 | 1 |
| **CO3** | 2 | 1 |
| **CO4** | 2 | 1 |
| **CO5** | 1 | 2 |
| **CO6** | 2 | 2 |

**Syllabus**

**Soft Skills**

**Corporate Culture and Managing Diversity**: Understanding Corporate Culture & Organizational Values, Corporate Culture in Indian & Global Organizations

Unconscious Bias, Adapting to Corporate Culture as a New Professional, Diversity Policies & Best Practices

**Critical Thinking & problem solving**: Problem Identification & Problem Framing, Problem solving process, Handling Ambiguity & Open-Ended Problems, Brainstorming techniques for Critical Thinking, Agile Thinking & Continuous Improvement

**Conflict Management**: Intrapersonal, Interpersonal & Task-Based Conflict, Conflict Management Styles, Steps in Conflict Resolution, Conflict in Hybrid & Remote Work Environments, Learning from Conflict

**Team building and working effectively in teams**: Communication & Collaboration in Teams, Stages of Team Development, Diversity, Inclusion & Cultural Sensitivity in Teams, Trust, Accountability & Psychological Safety, Leadership Dynamics

**Group discussion**: Critical Thinking & Perspective Building, Clarity, Fluency & Professional Language, Body Language & Eye Contact, Handling Interruptions & Disagreements, Self-Reflection & Improvement

**Interview skills:** Types of Interviews (Technical, HR, Managerial, Research), Understanding Job Descriptions & Role Expectations, Competency-Based & Behavioural Interviews, STAR Technique for Behavioral Questions, AI-Based Interview Screening & Preparation, Interview Netiquette & Modern Interview Contexts

**Mock Interview:** One on one Mock interview process for all the students

**Verbal**

**Vocabulary:** Enhance vocabulary skills through focused practice in idioms, phrasal verbs, and sentence completion, with emphasis on contextual usage and MCQ-based strategies.

**Grammar:** Develop grammatical accuracy by training students to identify and correct sentence-level errors through sentence correction and cloze test practice.

**Reasoning:** Strengthen critical reasoning and logical thinking skills through systematic practice in critical reasoning questions and logical ordering of sentences.

**Reading Comprehension:** Equip students with effective strategies to analyze and respond to reading comprehension passages through guided discussion and practice.

**Public Speaking Skills:** Enhance oral communication through storytelling for professional success and personal branding, and assess speaking competence through individual speeches and open forum discussions on current affairs.

**Commented [M[3]:** We have introduced Corporate Culture and Managing Diversity to expose learners to advanced corporate values and the nuances of working in diverse teams. Agile Thinking helps handle ambiguity and enhance critical thinking through effective brainstorming. Team Building develops skills to work effectively across generations, while Interviewing Skills, including AI-Based Screening and modern interview contexts, prepare learners for the evolving recruitment landscape.

**Writing Skills / Professional Communication:** Develop formal writing competence with emphasis on professional email etiquette and the drafting of job application and workplace emails.

**Commented [A(4]:** The second-semester verbal course is designed as a progression to the next level from the first semester, building on the foundations established in the first semester. It deepens students' **verbal ability** by refining vocabulary, grammar, reasoning, and reading comprehension skills through higher-order, application-oriented practice aligned with placement tests, competitive examinations, and professional assessments. Simultaneously, the course advances **communication skills** by focusing on public speaking, professional writing, and workplace communication, enabling students to articulate ideas with clarity, confidence, and strategic intent. Through integrated practice in speaking, reading, and writing, the course prepares PG students to function effectively in complex academic, professional, and corporate environments.

**Aptitude**

**Sequence, Series, Geometry -** 2D, 3D, Coordinate Geometry, and Heights & Distance, **Permutations & Combinations –** Circular & Linear Arrangements and Derangements, **Probability -** Addition & Multiplication Theorems and Conditional Probability, **Logical Reasoning -** Arrangements, Sequencing, Scheduling, Venn Diagram, Network Diagrams, Binary Logic, and Logical Connectives, Clocks, Calendars, Cubes, Non-Verbal reasoning, Blood Relations, Direction Test, Syllogisms, Series, Odd One Out, Coding & Decoding, Cryptarithmetic and Input-Output Reasoning, **Data Sufficiency, Campus Recruitment Papers, Puzzles -** Lateral Thinking Problems, Riddles, Logical Puzzles, Deduction Puzzles, Calculation Puzzles, and Other Interview Puzzles, **Time Management Strategies**.

**References**

**Soft Skills**


1. Student's Guide for Career Planning, CIR
2. Thomas L. Quick, "Successful team building", AMACOM Div American Mgmt Assn, 1992
3. Brian Cole Miller, "Quick Team-Building Activities for Busy Managers: 50 Exercises That Get Results in Just 15 Minutes", AMACOM; 1 edition, 2003.
4. Patrick Lencioni, "The Five Dysfunctions of a Team: A Leadership Fable", Jossey-Bass, 1st Edition, 2002
5. How to Win Friends & Influence People, Dale Carnegie, 1998 Edition.
6. I'm OK--You're OK, Thomas A. Harris, 2012 Edition.
7. Personality Development and Soft Skills, Barun K.Mitra, Oxford, 2nd Edition
8. Effective Group Discussion, Theory and Practice, Gloria J. Galanes McGraw Hill, 15th Edition


**Verbal**


1. Verbal Skills Workbook (PG), CIR
2. "GMAT Official Guide" by the Graduate Management Admission Council, 2019
3. Arun Sharma, "How to Prepare for Verbal Ability And Reading Comprehension For CAT"
4. Joern Meissner, "Turbocharge Your GMAT Sentence Correction Study Guide", 2012
5. Kaplan, "Kaplan GMAT 2012 & 13"
6. Kaplan, "New GMAT Premier", Kaplan Publishing, U.K., 2013
7. Manhattan Prep, "Critical Reasoning 6th Edition GMAT"
8. Manhattan Prep, "Sentence Correction 6th Edition GMAT"
9. Mike Barrett "SAT Prep Black Book The Most Effective SAT Strategies Ever Published"

10. Mike Bryon, “Verbal Reasoning Test Workbook Unbeatable Practice for Verbal Ability, English Usage and Interpretation and Judgement Tests”
11. www.bristol.ac.uk/arts/skills/grammar/grammar_tutorial/page_55.htm
12. www.campusgate.co.in

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