3rd Semester Robotics and AI Syllabus 2025 Scheme

Discrete Mathematics and Probability Theory

Course Code	**1BRI301**	Scheme	2025
Type of Course	**Applied Science Course**	Semester	3
Teaching Hours/Week (L:T:P)	42: 28: 00	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42:28:00:50	SEE Marks	50
Credits	**4**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

CO1: Apply principles of mathematical logic, proof techniques, relations, and functions to analyze and solve discrete mathematical problems.

CO2: Solve combinatorial problems using counting techniques, recurrence relations, inclusion–exclusion principle, generating functions, and related discrete structures.

CO3: Analyze probabilistic models involving random variables, probability distributions, conditional probability, and Bayes' theorem for uncertainty quantification.

CO4: Evaluate statistical characteristics of data using probability distributions, moment generating functions, sampling distributions, and the Central Limit Theorem.

Module-1

Mathematical Logic and Proof Techniques

Propositions and logical operations, truth tables, logical equivalence, predicates and quantifiers, rules of inference, validity of arguments, mathematical reasoning.

Methods of proof: direct proof, proof by contraposition, proof by contradiction, proof by cases and mathematical induction.

Number of Hours:08

Module-2

Relations and Functions

Relations and their properties, equivalence relations and partitions, partial order relations.

Matrix representation of relations, directed graph representation of relations, transitive closure of relations, Warshall's algorithm.

Functions and their types: injective, surjective and bijective functions, composition and inverse functions, permutations and applications in computer science.

Number of Hours:08

Module-3

Combinatorics

Basic counting principles, permutations and combinations, combinations with repetition.

Linear recurrence relations, Fibonacci sequence and applications.

Principle of Inclusion and Exclusion, generalized inclusion-exclusion, derangements and applications. Generating functions, Catalan numbers and applications.

Number of Hours:09

Module-4

Probability Theory and Random Variables

Finite Sample Space, Probability, Conditional Probability and Independence, Bayes' Theorem. One-Dimensional Random Variable: Discrete and Continuous Random Variable, Probability Functions, Cumulative Distribution Function, Expectation and Variance. Joint Distribution, Probability Density Function, Marginal Distribution, Expectation, Variance, Covariance and Correlation.

Number of Hours:09

Module-5

Probability Distributions and Sampling Theory

Moment Generating Function – Properties and Simple Problems, Binomial, Poisson,Uniform, Normal and Exponential Distributions.

Random Sample, Sample Mean, Sample Variance, Sampling Distribution of Mean, Central Limit Theorem, Sampling Distributions of Proportions.

Number of Hours:08

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Discrete Mathematics and Its Applications, Kenneth H. Rosen, 8th Edition, McGraw-Hill Education, 2019.
2. Probability and Statistics for Engineers and Scientists, Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers and Keying Ye, 9th Edition, Pearson Education, 2017.

Reference books / Manuals:

1. Discrete and Combinatorial Mathematics: An Applied Introduction, Ralph P. Grimaldi, 5th Edition, Pearson Education, 2004.
2. Discrete Mathematics, Seymour Lipschutz and Marc Lipson, Schaum's Outline Series, 3rd Edition, McGraw-Hill Education, 2009.
3. Introduction to Probability Models, Sheldon M. Ross, 12th Edition, Academic Press, 2019.
4. Probability, Statistics and Random Processes, T. Veerarajan, 4th Edition, McGraw-Hill Education, 2017.
5. Schaum's Outline of Probability and Statistics, Murray R. Spiegel, John Schiller and R. Alu Srinivasan, 4th Edition, McGraw-Hill Education, 2013.

Web links and Video Lectures (e-Resources):

1. **https://ocw.mit.edu/courses/6-1200j-mathematics-for-computer-science-spring-2024/?utm_source=chatgpt.com**
2. **https://tutorial.math.lamar.edu/?utm_source=chatgpt.com**
3. **https://www.khanacademy.org/math/statistics-probability?utm_source=chatgpt.com**

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Problem-Based Learning (PBL): Students solve real-world problems involving logical reasoning, combinatorial counting, probability, and statistical decision-making to strengthen analytical and problem-solving skills.
2. Activity-Based Learning using Mathematical Software: Use tools such as Python, Jupyter Notebook, GeoGebra, Wolfram Alpha, or MATLAB to visualize relations, graph structures, probability distributions, and sampling concepts.
3. Group Problem Solving: Small groups work on complex counting, recurrence relation, and probability problems, fostering teamwork and peer learning.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks.**

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1.	Solve and present real-world problems involving logic, relations, functions, combinatorics, and recurrence relations.	25
2.	Perform probability simulations and analyze random variables, probability distributions, and sampling concepts using computational tools	25

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each

Performance Indicator	Superior (5)	Good (4)	Fair (3)	Needs Improvement (2)	Unacceptable (1)
Understanding of Probability Concepts (CO3, PO1)	Demonstrates comprehensive understanding of probability and statistical concepts.	Demonstrates good understanding with minor errors.	Demonstrates basic understanding with some misconceptions.	Limited understanding of concepts.	Unable to demonstrate understanding.
Analysis and Computational Implementation (CO4, PO2, PO5)	Correctly performs simulations/analysis and obtains accurate results.	Performs analysis with minor computational errors.	Analysis is partially correct with noticeable errors.	Analysis is incomplete or largely incorrect.	Unable to perform analysis.
Interpretation and Reporting of Results (CO4, PO10)	Accurately interprets results and presents conclusions effectively.	Interpretation is generally correct with minor gaps.	Basic interpretation provided but lacks depth.	Interpretation is weak or unclear.	No meaningful interpretation of results.

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1.	Logic and combinatorics problem-solving activity.	10
2.	Probability modelling and simulation activity.	10

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.	Study of applications of discrete mathematics and probability in Robotics and Artificial Intelligence.	15
2.	Completion of online learning modules and preparation of a technical report.	15

Continuous Internal Evaluation (CIE)

1. The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
2. Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
3. The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
4. A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

1. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
2. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
3. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

<table>
<tr><th colspan="4">Data Structures and Algorithms</th></tr>
<tr><td>Course Code</td><td>1BRI302</td><td>Scheme</td><td>2025</td></tr>
<tr><td>Type of course</td><td>Integrated Professional Core Course (IPCC)</td><td>Semester</td><td>03</td></tr>
<tr><td>Teaching Hours/Week (L:T:P)</td><td>3 : 0 : 2</td><td>CIE Marks</td><td>50</td></tr>
<tr><td>Total Hours of Pedagogy L:T:P:SL:TW</td><td>42 : 0 : 28 : 20 : 30</td><td>SEE Marks</td><td>50</td></tr>
<tr><td>Credits</td><td>04</td><td>Total Marks</td><td>100</td></tr>
<tr><td>Type of Examination (IPCC):</td><td>Theory - CIE +SEE, and Lab - CIE only.</td><td>Exam Hours</td><td>03</td></tr>
</table>

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Explain the fundamentals of algorithmic analysis and select appropriate data structures for engineering problems.
2. Implement arrays, stacks, queues and linked lists for mechatronics and robotics data-handling applications.
3. Apply trees, hashing and priority-based structures to organize, retrieve and process engineering data efficiently.
4. Analyse graph representations and traversal algorithms for robotic navigation, automation networks and connectivity problems.
5. Design and demonstrate C/Python-based DSA solutions for interdisciplinary engineering problems using laboratory practice and documentation.

Module-1

Introduction, Stacks, Queues: Introduction to data structures and algorithms; algorithm analysis; time and space complexity; arrays and dynamic arrays; applications in sensor buffers and actuator command sequences; stacks and queues; stack applications; queue applications in job scheduling and sensor streams.

Number of Hours: 08

Module-2

Linked List, Recursion: Singly linked lists, circular linked lists and doubly linked lists; insertion, deletion and traversal; memory representation; recursion; recursive problem-solving; engineering examples: robot task lists, route checkpoint lists and recursive search problems.

Number of Hours: 08

Module-3

Trees: Tree terminology; binary trees; binary search trees; tree traversals; heaps and priority queues; applications in decision logic, task priority scheduling, sensor-event ranking and hierarchical representation of robotic subsystems.

Number of Hours: 08

Module-4

Searching and Sorting: Linear search and binary search, bubble sort, selection sort, insertion sort, merge sort and quick sort; comparison of sorting methods along with their computing efficiencies; hashing concepts; collision resolution; applications in lookup tables, component identification, machine state retrieval and maintenance record indexing.

Number of Hours: 08

Module-5

Graphs and Navigation: Graph terminology and representations; adjacency matrix and adjacency list; BFS and DFS with computing efficiencies; connected components; shortest path overview; minimum spanning tree concepts; Prim and Kruskal algorithms with computing efficiencies; applications in mobile robot navigation, automation cell layout, network connectivity and path planning abstractions.

Number of Hours: 08

PRACTICAL COMPONENTS OF IPCC

FIXED SET OF EXPERIMENTS

1. Implement an array-based data processing program to store sensor readings and compute the number of readings, minimum value, maximum value, average value and range using sample data from temperature, water-level, distance or motor-speed sensors.
2. Design and demonstrate stack operations such as push, pop, peek and display, and apply the stack to reverse actuator commands or verify the correct order of machine-operation steps.
3. Construct a queue-based task processing program to perform insertion, deletion and display operations for robot movement commands, workshop job scheduling, pump requests or sensor-data buffering.
4. Implement a singly linked list to perform insertion, deletion, searching and traversal operations for maintaining robot task IDs, machine service records or route checkpoint numbers.
5. Model a doubly linked list to support insertion, deletion, forward traversal and reverse traversal for representing robot forward–reverse movement, conveyor stations or inspection checkpoints.
6. Apply recursion to solve selected computational problems such as factorial, Fibonacci series, binary search or Tower of Hanoi, and trace the recursive calls to understand repeated engineering tasks.
7. Construct a binary search tree and perform insertion, searching, inorder traversal, preorder traversal and postorder traversal using component IDs, tool numbers, sensor-event IDs or machine-part codes.
8. Implement a heap or priority queue to arrange tasks according to priority, using examples such as emergency stop alerts, robot job priority, maintenance requests or sensor warning levels.
9. Evaluate linear search and binary search using a list of component numbers, tool IDs, machine IDs or student roll numbers, and compare the number of comparisons required by each method.
10. Analyse the performance of sorting algorithms such as bubble sort, insertion sort and quick sort by sorting motor speeds, sensor values, component IDs or student marks.
11. Implement hashing using linear probing or chaining to store and retrieve machine IDs, component numbers, employee IDs or tool codes, and demonstrate collision handling.
12. Model a simple path or network using graph representation and perform BFS and DFS traversal for robot movement between locations, workshop-station connectivity, warehouse route planning or automation-cell layout.

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Ellis Horowitz, Sartaj Sahni and Susan Anderson-Freed, Fundamentals of Data Structures in C, 2nd Ed., Universities Press, 2014.
2. Robert Sedgewick and Kevin Wayne, Algorithms, 4th Ed., Addison-Wesley / Pearson, 2011.
3. Reema Thareja, Data Structures Using C, 3rd Ed., Oxford University Press, 2025.

Reference books / Manuals:

6. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein, Introduction to Algorithms, 4th Ed., MIT Press, 2022.
7. Mark Allen Weiss, Data Structures and Algorithm Analysis in C++, 4th Ed., Pearson, 2014.
8. Gilberg and Forouzan, Data Structures: A Pseudo-code Approach with C, 2nd Ed., Cengage Learning, 2014.
9. Seymour Lipschutz, Data Structures, Schaum’s Outlines, Revised 1st Ed., McGraw Hill, 2014.

Web links and Video Lectures (e-Resources):

1. NPTEL: Data Structures and Algorithms: https://nptel.ac.in/courses/106102064
2. NPTEL YouTube Playlist: Data Structures and Algorithms: https://www.youtube.com/playlist?list=PLBF3763AF2E1C572F
3. MIT OpenCourseWare: Introduction to Algorithms: https://ocw.mit.edu/courses/6-006-introduction-to-algorithms-spring-2020/
4. Princeton University: Algorithms, Part I: https://online.princeton.edu/algorithms-part-i
5. VisuAlgo: Data Structure and Algorithm Visualization: https://visualgo.net/
6. University of San Francisco: Data Structure Visualizations: https://www.cs.usfca.edu/~galles/visualization/Algorithms.html
7. Virtual Labs, IIIT Hyderabad: Data Structures Lab: https://ds1-iiith.vlabs.ac.in/
8. Virtual Labs, IIIT Hyderabad: Stacks and Queues Experiment: https://ds1-iiith.vlabs.ac.in/exp/stacks-queues/index.html
9. Virtual Labs, IIIT Hyderabad: Linked List Basics: https://ds1-iiith.vlabs.ac.in/exp/linked-list/basics/overview.html
10. Virtual Labs, IIIT Hyderabad: Tree Traversal Experiment: https://ds1-iiith.vlabs.ac.in/exp/tree-traversal/index.html

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. **Flipped Classroom:** Students may watch short videos or read simple notes on stacks, queues, linked lists, trees, hashing or graphs before the class. Classroom time shall be used for algorithm tracing, dry run, discussion and implementation. **Simple Evaluation Method:** Faculty may conduct a 5-minute quiz, ask students to explain one concept, or collect a short pre-class note.
2. **Problem-Based Learning (PBL):** Each module may begin with a practical engineering problem such as robot task scheduling, machine ID searching, sensor-data handling, priority alert processing or path traversal. Students shall identify the suitable data structure and implement the solution. **Simple Evaluation Method:** Faculty may evaluate a short worksheet containing the problem statement, selected data structure, reason for selection, algorithm steps and expected output.
3. **Case-Based Teaching:** Faculty may explain DSA concepts using simple cases from robotics, automation, mechatronics systems, conveyor control, warehouse movement, machine maintenance and component tracking. **Simple Evaluation Method:** Students may submit a brief case interpretation note explaining where the data structure is used and why it is suitable.
4. **Simulation and Virtual Labs:** Stack operations, queue scheduling, linked-list pointer movement, recursion, tree traversal, hashing collision handling and graph traversal may be demonstrated using simple simulators, virtual labs or classroom diagrams. **Simple Evaluation Method:** Faculty may ask students to complete a dry-run table or trace the output for a given input.
5. **ICT-Enabled Teaching:** Google Colab, Jupyter Notebook, online C compilers, Python Tutor, algorithm visualizers and LMS quizzes may be used for demonstration, practice and submission. **Simple Evaluation Method:** Faculty may evaluate execution screenshots, submitted source code, LMS quiz marks or program output files.
6. **Peer Instruction and Debugging Sessions:** Students may work in pairs to identify syntax errors, logical errors, pointer mistakes, wrong traversal order, recursion errors and incorrect outputs. **Simple Evaluation Method:** Faculty may use a peer-debugging checklist where students identify errors, suggest corrections and verify the corrected output.
7. **Industry/Workshop-Oriented Examples:** Examples from robotic arms, AGVs, CNC machines, drones, automated production lines, warehouse robots, sensors and maintenance systems may be used to show real-world relevance. **Simple Evaluation Method:** Students may map one industry example to a suitable data structure or algorithm and justify the selection in 3–5 lines.
8. **Micro Project-Based Learning:** Students may complete a small activity such as robot task manager, machine maintenance record system, component search system, sensor alert priority system or simple route traversal model. **Simple Evaluation Method:** Faculty may evaluate based on problem understanding, correct data structure usage, working code, output explanation and documentation.

Assessment Structure:
The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).
The CIE Theory component will be **25 marks** and CIE Practical component will be **25 marks.**

The CIE Theory component consists of IA tests for 25 marks. The CIE Practical component for continuous assessments will be for 15 marks through rubrics and for lab tests will be for 10 marks.

- To qualify and become eligible to appear for SEE, in the **CIE theory component**, a student must score at least **40% of 25 marks**, i.e., **10 marks**.
- To qualify and become eligible to appear for SEE, in the **CIE Practical component**, a student must secure **a minimum of 40% of 25 marks**, i.e., **10 marks**.
- To pass the **SEE**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

CIE Practical component:
The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. The summation of all the experiments marks to be scaled down to 15 marks.
The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and scaled down to 10 marks. For laboratory test, the student is required to conduct one experiment.

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Suggested rubrics for Practical continuous assessment:

Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)

Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output (3)	Student will be able to run the program but not able to analyze the output (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.		
2.		

3.		
4.	(Add rows if required)	
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.		
2.		
3.		
4.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

(i)Theory component

The CIE marks of 25 shall be earmarked for two tests.

The first test shall be conducted after completing two modules of the syllabus and the second one after completing the rest three modules.

Each test shall be conducted for 25 marks. The average of the two tests scaled down to 25 marks shall constitute the test marks for a maximum of 25 marks.

(ii) Laboratory component

Out of 25 marks, 15 marks shall be assigned for assessment as per the rubrics listed in the course syllabus.

The remaining 10 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for regular class work and practical test as indicated in the Table – ICs/IPCCs 1.

(i) To qualify and become eligible to appear for the SEE of the IC/IPCC, a student shall secure at least 40 % of 25 marks, i.e., 10 marks, in the CIE theory component, and at least 40 % of 25 marks, i.e., 10 marks in the CIE Practical component.

Table – ICs/IPCCs 1 Distribution of marks		
Component	**Description**	**Marks**
Allotment of marks for regular class work		
Ability in Conducting Experiments	Initiative, skill, safety practices, teamwork, and independent handling of equipment during regular lab sessions.	5 marks
Laboratory Record / Journal	Regular and neat maintenance of lab record, accuracy of results, and timely submission.	10 marks
	Subtotal	**15**
Allotment of marks for CIE practical test		
Laboratory Test / Experiment Performance	Ability to set up apparatus, follow procedure, take observations, and obtain correct results in the test experiment.	5 marks
Viva-Voce	Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.	5 marks
	Subtotal	**10**
	Total	**25**

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

MECHANICS OF MATERIALS			
Course Code	**BRI303**	Scheme	2025
Type of Course	**Professional Core Course**	Semester	3
Teaching Hours/Week (L:T:P)	3:1:0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42: 28:0:50	SEE Marks	50
Credits	**4**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

- **CO1:** Apply the concepts of stress, strain, elastic constants, and deformation to analyze axially loaded structural members.
- **CO2:** Determine principal stresses, maximum shear stresses, and their orientations in bi-axial stress systems using analytical and graphical methods.
- **CO3:** Construct shear force and bending moment diagrams and evaluate bending and shear stresses in beams subjected to different loading conditions.
- **CO4:** Analyze torsional behaviour of solid and hollow circular shafts and evaluate their strength, stiffness, and power transmission capabilities.

Module-1

Simple stress and strain: Definition/derivation of normal stress, shear stress, and normal strain and shear strain – Stress strain diagram for brittle and ductile materials - Poisson's ratio & volumetric strain.

Elastic constants – relationship between elastic constants and Poisson's ratio – Hook's law – Deformation of simple and compound bars.

Number of Hours:08

Module-2

Bi-axial Stress system: Introduction, plane stress, stresses on inclined sections, principal stresses and maximum shear stresses

Graphical method - Mohr's circle for plane stress.

Number of Hours:10

Module-3

Bending moment and Shear forces in beams: Definition of beam – Types of beams – Concept of shear force and bending moment.

S.F and B.M diagrams for cantilever, simply supported and overhanging beams subjected to point loads, uniformly distributed loads.

Number of Hours:08

Module-4

Theory of simple bending – Assumptions – Derivation of bending equation - Neutral axis – Determination of bending stresses – section modulus of rectangular and circular sections (Solid and Hollow).

Shear Stresses: Derivation of formula – Shear stress distribution across various beams sections like rectangular, circular.

Number of Hours:08

Module-5

Torsion of circular shafts: Introduction, pure torsion, assumptions, derivation of torsional equations, polar modulus,

Torsional rigidity / stiffness of shafts, power transmitted by solid and hollow circular shafts.

Number of Hours:08

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

4. Strength of Materials, R.K. Rajput, *Strength of Materials (Mechanics of Solids)*, S. Chand Publishing, 2022.
5. Mechanics of Materials, R.C. Hibbeler, *Mechanics of Materials*, Pearson Education, 2024.
6. Strength of Materials, S.S. Bhavikatti, *Strength of Materials*, Vikas Publishing House, 2023.

Reference books / Manuals:

1. Mechanics of Materials, Beer, Johnston, DeWolf and Mazurek, *Mechanics of Materials*, McGraw-Hill Education.
2. Mechanics of Materials, Gere and Goodno, *Mechanics of Materials*, Cengage Learning.
3. Strength of Materials, S. Ramamrutham, *Strength of Materials*, Dhanpat Rai Publications.
7. Mechanics of Solids, Timoshenko and Goodier, *Theory of Elasticity / Mechanics of Solids*, McGraw-Hill.

Web links and Video Lectures (e-Resources):

1. https://onlinecourses.nptel.ac.in/e-learning/preview/noc21_ce38
2. https://www.youtube.com/results?search_query=engineering+mechanics
3. https://onlinecourses.nptel.ac.in/e-learning/preview/noc24_me145
4. https://onlinecourses.nptel.ac.in/e-learning/preview/noc23_ce57
5. https://www.youtube.com/@TheEfficientEngineer

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Virtual Labs to visualize stress-strain behaviour
2. Static analysis simulations can be performed in FEA packages

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks.**

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
3	Analyse a robotic structural element such as a manipulator link, robot arm, gripper finger, mobile robot chassis member, or servo motor shaft. Determine the stresses, bending moments, torsional stresses, and/or deflection under specified loading conditions using analytical calculations and/or simulation tools. Students shall submit a technical report and present their findings.	25

Performance Indicator (CO/PO Mapping)	Superior (5)	Good (4)	Fair (3)	Needs Improvement (2)	Unacceptable (1)
Performance Indicator-1: Problem Definition and Structural Modelling (CO1, PO1)	Clearly defines the problem with appropriate assumptions, dimensions, loading conditions, constraints, and accurate free-body diagrams.	Problem definition and modelling are mostly correct with minor omissions.	Basic problem definition provided; some assumptions or loading details are incomplete.	Problem formulation lacks clarity and contains significant omissions.	Problem is poorly defined or incorrectly modelled.
Performance Indicator-2: Stress/Bending/Torsion Analysis **(CO2, CO3, CO4, PO1)**	Performs complete and accurate analysis with correct determination of stresses, bending moments, torsional stresses, and/or deflection.	Analysis is substantially correct with minor computational errors.	Analysis is partially correct but contains noticeable errors.	Analysis is incomplete with major conceptual or calculation errors.	Unable to perform the required analysis.
Performance Indicator-3: Application and Interpretation of Results (CO3, CO4, PO2)	Accurately interprets results and provides sound engineering conclusions regarding strength, stiffness, and suitability of the component.	Interpretation is generally correct with minor shortcomings.	Basic interpretation provided with limited engineering insight.	Interpretation is weak and poorly justified.	No meaningful interpretation of results.
Performance Indicator-4: Technical Report and Documentation **(CO1–CO4, PO10)**	Report is exceptionally well-organized with clear calculations, figures, tables, discussions, and conclusions.	Report is well-structured with minor deficiencies.	Report is adequate but lacks completeness in some sections.	Report is poorly organized with missing information.	Report is incomplete or not submitted.
	Presents findings	Good			

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
3.	Structural Analysis of Links of Robot Arm	26
4.	Structural Analysis of Robot Grippers	24
5.		
6.	(Add rows if required)	

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
3.		
4.		
5.		
6.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

5. The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
6. Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
7. The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
8. A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

4. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
5. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
6. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Analog & Digital Electronics			
Course Code	**1BRI304**	Scheme	2025
Type of Course	**PCC**	Semester	3
Teaching Hours/Week (L:T:P)	3: 0 : 0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42: 0 : 0 : 48	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Explain the operation and characteristics of diodes, BJTs, rectifiers, and voltage regulation circuits used in basic electronic systems.
2. Analyze JFETs, MOSFETs, Op-Amps, and Class A/Class B amplifiers for analog signal processing applications.
3. Design and evaluate active filters, ADC/DAC circuits, and digital building blocks such as logic gates,
4. Boolean expressions, and combinational circuits used in embedded and robotics systems.
5. Simplify Boolean expressions and design digital systems such as adders, multiplexers, flip-flops, counters, shift registers, and FSM-based controllers.

Module-1

Diode Characteristics & Applications:

Introduction to electronic components and semiconductor materials, PN junction diode: operation and characteristics, Rectifiers: Half-Wave, Full Wave, Power Supply using full wave rectifiers, Power Supply testing & performance, Voltage Regulation, Zener Diode Voltage Regulators. Special Diodes: LED, Photodiode

Bipolar Junction Transistors & Applications:

BJT Operation, BJT Voltage and Currents, BJT Amplification, BJT Switching, Common-Emitter Characteristics, Common Collector Characteristics

Number of Hours: 8

Module-2

Field Effect Transistors:

Junction Field Effect Transistors, JFET Characteristics, FET Amplification & Switching, MOSFETs

Operational Amplifiers:

Differential Amplifier Circuits, Op-Amp Basics, Op-Amp Specifications, Op-Amp Applications: Constant Gain Multiplier, Voltage Buffers, Controlled Sources, Instrumentation Circuits

Power Amplifiers:

Introduction, Class A and Class B Amplifier Operation, Applications

Number of Hours: 8

Module-3

Acitve Filters

Filter Types and Characteristics, First-Order Active Filters, Higher-Order Active Filter, Second-Order High Pass Filters

Linear-Digital ICs

Introduction to Integrated Circuits, IC fabrication basics, Monolithic and hybrid ICs, Comparator, Digital to Analog Converters, Analog to Digital Converters: Successive Approximation ADC, Flash ADC, Sigma-Delta ADC (Characteristics, Block diagram, Typical Applications), Interfacing Circuits.

Number of Hours: 8

Module-4

Number of Systems

Digital Computers & Digital Systems. Binary Numbers, Hexadecimal, Gray Code

Boolean Algebra and Logic Gates

Basic Definitions, Basic Theorems and Properties of Boolean Algebra, Boolean Functions, Canonical and Standard Forms, IC Digital Logic Families

Simplification of Boolean Functions

The Map Method, Two & Three Variable Maps, Four Variable Map, POS Simplification, NAND and NOR Implementation

Number of Hours: 08

Module-5

Combinational Logic

Adders and Subtractors, Binary parallel Adder, Code Conversion, Multiplexers and Demultiplexers, Encoders and Decoders

Sequential Logic

Flip-Flops, Latches, Triggering Flip-Flops, Registers and shift registers, Counters

Number of Hours: 08

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Electronics Devices, David A Bell,5th Edition, Oxford University Press, ISBN-13:978-0-19-569340-9
2. Electronic Devices and Circuit Theory, Robert L. Boylestad, Louis N. Nahelsky, 11th Edition, Pearson Education, ISBN:978-93-325-4260-0
3. Digital Logic and Computer Design, M Morris Mano, Pearson Education, ISBN:978-93-325-4252-5
4. Digital Fundamentals, Thomas L. Floyd, 11th Edition, Pearson Education, 2025, ISBN: 9781292485263.

Reference books / Manuals:

1. Microelectronic Circuits, Adel S. Sedra and Kenneth C. Smith, 8th Edition, Oxford University Press, 2020.
2. Digital Design, M. Morris Mano and Michael D. Ciletti, 6th Edition, Pearson Education, 2018.
3. Op-Amps and Linear Integrated Circuits, Ramakant A. Gayakwad and S. Rekha, 4th Revised Edition, Pearson Education India, 2021, ISBN: 9789353949037.

Web links and Video Lectures (e-Resources):

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching learning process and facilitate the achievement of course outcomes.

1. Flipped Classroom Learning: Students learn theory (videos/NPTEL) before class; class time is used for problem solving and circuit discussions.
2. Simulation-Based Learning: Use tools like LTspice, Multisim, Proteus to design and analyse analogue circuits (diodes, op-amps, filters).
3. Logisim-Based Digital Design: Digital circuits like adders, flip-flops, counters, and FSMs are implemented and verified using Logisim Evolution.
4. Project-Based Learning (PBL)
5. Problem-Based Learning (PBL)
6. Open-ended design problems
7. Hardware Hands-on Experiments
8. Peer Learning & Group Activities

Assessment Structure:
The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks.**

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks.**

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
4.		
5.		

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
7.		
8.		
9.		
10.	(Add rows if required)	
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
7.		
8.		
9.		
10.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

Fundamentals of Industrial Robots			
Course Code	**1BRI305**	Scheme	2025
Type of Course	**PCC**	Semester	3
Teaching Hours/Week (L:T:P)	3:0 :0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42: 00: 00: 48	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Understand the significance, social impact and future prospects of robotics and automation in various engineering applications.
2. Identify and describe the components and anatomy of robotic system.
3. Know about various path planning techniques and analyze different motions of robotics system
4. Use the suitable drives and end-effectors for a given robotics application.
5. Apply robotics concept to automate the monotonous and hazardous tasks and categorize various types of robots based on the design and applications in real world scenarios.

Module-1

INTRODUCTION TO ROBOTICS: Introduction to Robotics, robot, laws of robot, brief history of robotics, basic components of robot, robot specifications, human system and robotics.

Classification and applications: Types of Robots- Manipulators, Mobile Robots-wheeled: classification based on wheel configurations, Legged Robots: classification based on number of legs, Aerial Robots, open kinematic vs closed kinematic chain, safety measures in robotics, social impact, Robotics market, and the prospects, advantages and disadvantages of robots.

Number of Hours: 8

Module-2

ROBOT ANATOMY AND MOTION ANALYSIS: Anatomy of a robotic manipulator-links, joints, actuators, sensors, controller, Robot configurations: polar, cylindrical, Cartesian, jointed arm configurations (Articulated and SCARA), Robot links and joints, Grashoff's law, Degrees of freedom (DoF): types of movements, vertical, radial and rotational traverse, roll, pitch and yaw, Work volume/envelope,
ROBOT KINEMATICS: Introduction to direct and inverse kinematics, transformations and rotation matrix, Numerical on transformation matrices: pure rotation, pure translation and

Module-3

ROBOT DRIVES AND END EFFECTORS: Robot drive systems: Hydraulic, Pneumatic and Electric drive systems, classification of end effectors, mechanical grippers, vacuum grippers, magnetic grippers, adhesive gripper, gripper force analysis and gripper design, 1 DoF, 2 DoF, multiple degrees of freedom robot hand, tools as end effectors,
ROBOT CONTROL TYPES: limited sequence control, point-to-point control, playback with continuous path control, and intelligent control.

Number of Hours: 8

Module-4

Robot Programming: Introduction to robot programming, history of robot programming, Methods of Robot Programming-Lead through, Textual, Lead through programming Methods-Powered and Manual lead through. Generations of Robot Programming Languages, Assembly language (AL), Victor's Assembly language I(VAL I), VAL II, Robot Language structure, Introduction to Robotic Operating System (ROS).
APPLICATION PROGRAMS: Syntax examples/programs on AL, VAL I, VAL II (Simple programs).

Number of Hours: 8

Module-5

Application of Robot: aerial robots helicopters, Multi rotor UAV, Flapping wing/Bio inspired UAV, wheeled mobile robots, swarm robots, Legged robots, medical/healthcare robots, Rehabilitation robot, hospital robot, space robots, service robots, Underwater and floating robots, Military Robots.
ROBOTICS APPLICATIONS: pick and place, palletizing and depalletizing, machining loading and unloading, welding & assembly, Medical, agricultural and space applications, unmanned vehicles: ground, robotic for computer integrated manufacturing, Industrial robots, Humanoids, Cobots, Autonomous robots

Number of Hours: 8

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. "Introduction to Robotics: Mechanics and Control" by John J. Craig.
2. Mikell P. Groover et. al., "Industrial Robots - Technology, Programming and Applications", McGraw Hill, Special Edition, (2012).
3. "A Gentle Introduction to ROS" by Jason M. O'Kane.
4. Ganesh S Hegde, "A textbook on Industrial Robotics", University science press, 3rd edition, 2017

Reference books / Manuals:

1. Richard D Klafter, Thomas A Chmielewski, Michael Negin, "Robotics Engineering – An Integrated Approach", Eastern Economy Edition, Prentice Hall of India Pvt. Ltd., 2006.
2. Fu K S, Gonzalez R C, Lee C.S.G, "Robotics: Control, Sensing, Vision and Intelligence", McGraw Hill, 1987. https://www.robots.com/applications.
3. .https://www.asme.org/engineering-topics/articles/bioengineering/top-6robotic- applications-inmedicine

Web links and Video Lectures (e-Resources):

https://roboticscasual.com/ros-tutorial-pick-and-place-task-with-the-moveit-c-interface/
https://roboticscasual.com/ros-tutorial-simulate-ur5-robot-in-gazebo-urdf-explained/
https://roboticscasual.com/the-best-degrees-to-work-in-robotics/
https://roboticscasual.com/robotics-tutorials/

https://www.ieee-ras.org/educational-resources-outreach/educational-material-in-robotics-and- automation
https://www.academia.edu/20361073/Web_Based_Control_and_Robotics_Education_pdf
https://github.com/Developer-Y/cs-video-courses

https://www.isa.org/

NPTEL / SWAYAM Video Lectures:

- ***Introduction to Robotics (IIT Madras / IIT Delhi):*** **Highly relevant introductory series covering basic robot anatomy, joint configurations (SCARA, Articulated), and spatial transformation matrices (Module 1 & 2).**

- ***Industrial Automation and Control:*** **Ideal video resource for studying hydraulic, pneumatic, and electric drive loops, alongside mechanical gripper force calculations (Module 3).**

Software Platforms & Simulated Environments:

- ***RoboGuide (FANUC) / RobotStudio (ABB):*** **Interactive trial platforms that vividly demonstrate modern industrial layout setups, robot programming (VAL equivalents), and playback controls (Module 4 & 5).**

- ***ROS (Robot Operating System) Wiki & Beginner Tutorials:*** **Fundamental web documentation introducing nodes, topics, and simple environment setups for robotic communication architecture (Module 4).**

Industrial Media & Application Case Studies:

- ***KUKA / Yaskawa Motoman YouTube Channels:*** **Direct video documentation showcasing real-world implementations of pick-and-place, spot welding, palletizing, and collaborative robot (cobot) configurations (Module 5).**

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Interactive Anatomy Mapping: Use physical laboratory manipulators or 3D CAD models to help students identify links, joints, and specific workspaces (polar, cylindrical, SCARA) to compute and verify a robot's overall Degrees of Freedom (DoF).

2. Matrix Transformation Problem-Solving Blocks: Conduct active classroom blackboard exercises focused on mapping sequential pure translations and rotations, helping students practice spatial coordinate tracking.

3. Comparative Hardware Demonstrations: Organize direct comparative showcases of electric, pneumatic, and hydraulic actuate mechanisms alongside different gripper designs (vacuum, magnetic) to evaluate payload-to-weight performance metrics.

4. Simulated Teach-Pendant & Language Programming: Utilize free offline robot programming simulation environments to guide students through manual lead-through paths, textual command syntax, and basic VAL-style logic construction.

5. Industry Application Deep-Dives: Assign structured presentation modules where students analyze real-world case studies of specialized field deployments, comparing the design constraints of surgical robots, agricultural UAVs, and shop-floor cobots.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

Sl. No.	Name of the Learning activity	Maximum Marks
1.	Software Exploration (MATLAB or Python libraries or ROBO ANALYSER or Adams or ROBO DK or any other software for Robots) for simulation	15
2.	Case Study Presentation selecting any robot based on application	10

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
11.		
12.		
13.		
14.	(Add rows if required)	
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
11.		
12.		
13.		
14.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Computer Aided Modelling Lab		Scheme	2025
Course Code	**1BRIL306**	Semester	3
Teaching Hours/Week (L:T:P)	0:0:2	CIE Marks	50
Total Hours of Pedagogy L:T:P:SLTW	0:0:28:2	SEE Marks	50
Credits	1	Total Marks	100
Examination type (SEE)	**Practical**	Exam Hours	2

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

6. Understand the concepts of CAD and CAD tools
7. Use, identify and explain standard features in solid modelling
8. Use standard software tools to assembly, drafting and introduce to apply GD&T in drawing
9. Engage in lifelong learning using sketching and drawing as communication tool

Note:

1. The laboratory syllabus consists of PART-A and PART-B. While PART-A has 6 conventional experiments, PART-B has 6 typical open-ended experiments. The maximum marks for the laboratory course are 100.
2. Both PART-A and PART-B are considered for CIE and SEE.
3. Students have answer 1(one) question from PART-A and 1(one) question from PART-B.
   a. The questions set for SEE shall be from among the experiments under PART-A. It is evaluated for **70 marks** out of the maximum 100 marks.
   b. The open-ended question set for SEE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for **30 marks.**
4. For Continuous Internal Evaluation (CIE) during the semester, classwork shall typically include open-ended questions from **Part-B**, along with other similar questions designed to enhance the students' skills.

PART – A
FIXED SET OF EXPERIMENTS

13. Introduction: Concept of Parametric Modelling, Feature Based Modelling, User Interface, Mouse operations, File types and Management, drawing profiles.
14. Sketcher: Profile toolbar, operation (corner, chamfer, delimitations, transformations, project 3D element), constraints, types of constraints, workbench, sketch tools, visualization toolbar, user selection filter.
15. Modelling: Modelling of Machined component, Material Addition and Removal, Sketch and Positioned Sketch, Types of Fillets, Types of Chamfers, Types of Hole, Pattern, Thread/Tap, Datum Features, Creation of different parts using above commands.
16. Drafting-Detailing Drawings. Explode a 3D model for a drawing, Create a drawing sheet and views, Add geometry and dimensions to a drawing, Add GD & T text, BOM, tables and symbols, Place an exploded view, Edit a title block, Export to different file formats.
17. Assembly: (Part drawings shall be given) any two assemblies Screw Jack, Plummer block, Bench vice
18. Limits, Fits and Tolerances: Introduction, Fundamental tolerances, Deviations, Methods of placing limit dimensions, Types of fits with symbols and applications, Geometrical tolerances on drawings, Standards followed in industry. GD & T symbols with their usage.

List of part drawings for assemblies: 1. Screw jack, 2. Plummer block 3. Machine wise 4. Connecting rod 5. Piston head 6. Tail stock.

PART – B
OPEN ENDED EXPERIMENTS

Open-ended experiments are a type of laboratory activity where the outcome is not predetermined and students are given the freedom to explore, design, and conduct the experiment based on the problem statements as per the concepts defined by the course coordinator. It encourages creativity, critical thinking, and inquiry-based learning.

1. Modelling and assembly of any robots based on application
2. Solving Simple Problems of Structural Analysis considering Design of robotic components.
3. Concept 3: robot components
4. Concept 4: robot components
5. Concept 5: robot components
6. Concept 6: robot components

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

8. **. 'A Primer on Computer Aided Machine Drawing-2007', Published by VTU, Belgaum.**
9. **. 'Machine Drawing', N.D.Bhat & V.M.Panchal, Published by Charotar Publishing House, 1999**
10. **. 'Machine Drawing', K.R. Gopala Krishna, Subhash publication**

Reference books / Manuals:

10. **. "A Text Book of Computer Aided Machine Drawing", S. Trymbakaa Murthy, CBS Publishers, New Delhi, 2007.**
11. **. 'Machine Drawing', N.Siddeshwar, P.Kannaih, V.V.S. Sastri, published by Tata Mc.Grawhill, 2006.**
12. **. K L Narayana, P Kannaiah, K Venkata Reddy, "Machine Drawing", New Age International, 3rd Edition. ISBN-13: 978-81-224-2518-5, 2006**
13. **Ajeet Singh, "MACHINE DRAWING", Tata McGraw-Hill Education, , ISBN: 9781259084607, 2012**

Web links and Video Lectures (e-Resources):

- https://www.autodesk.com/certification/learn/course/learn-fusion-360-in-90-minutes
- https://www.autodesk.com/certification/learn/course/fusion360-intro-modeling-design-professional

NPTEL / SWAYAM Video Lectures:

- *Computer Aided Design (CAD) / Computer Aided Engineering (IIT Kanpur / IIT Madras):* Highly recommended lecture series for understanding parametric modeling logic, feature-based modeling, and transformation matrices.
- *Engineering Graphics and Design / Machine Drawing:* Ideal visual modules for learning the standard practices of limits, fits, tolerances, and structural orthographic projection techniques.
- Software Learning Repositories & Video Manuals:
- *SolidWorks / Fusion 360 / CATIA Official Essentials Tutorials:* Comprehensive step-by-step video libraries introducing Sketcher workbenches, constraint management, and assembly constraints (coincident, concentric, mate).
- *GrabCAD Community Tutorials:* Excellent web platform showcasing industry-grade assemblies of 3D robot configurations, custom joints, and manufacturing drawings.
- GD&T and Standards Reference Hubs:
- *ASME Y14.5 / ISO GPS Geometric Dimensioning and Tolerancing Quick Guides:* Interactive web charts explaining GD&T symbols, feature control frames, and material modifiers (MMC/LMC).

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Live Desktop Screen-Casting Interventions: Deliver real-time, step-by-step software demonstrations on the main laboratory projector, highlighting optimal workflow constraints, profile tools, and user interface navigation tricks before students start individual drafting tasks.

2. Interactive Constraint Debugging Sessions: Present intentionally broken or "over-constrained" 2D profiles on screen, challenging students to find, analyze, and remove conflicting parametric constraints to make the sketch fully defined.

3. Exploded Assembly-to-Drafting Linkage Projects: Provide students with standard 3D multipart models (e.g., a Screw Jack or Plummer Block) and guide them to visually manipulate assembly mates, build dynamic exploded views, and directly generate formal Bills of Materials (BOM).

4. Peer-Review Drawing Checks Using Industry Standards: Coordinate peer-review exercises where students trade their final 2D blueprint sheets to verify that limits, fits, tolerances, and GD&T symbol applications comply with formal industrial drafting standards.

5. Open-Ended Robotic Reverse-Engineering Projects: Guide student teams through Part-B open-ended tasks where they conceptualize, sketch, model, and assemble custom multi-axis robot sub-assemblies based on functional real-world constraints

Assessment Structure:
The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.
For both CIE and SEE, the student is required to conduct one experiment each from both Part A and Part B.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment

Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to

	with proper analysis. (5)			analyze the output. (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Analog and Digital Electronics Laboratory

Course Code	**1BRIL307**	Scheme	2025
Type of Course	Ability Enhancement Course (Laboratory)	Semester	3
Teaching Hours/Week (L :T : P)	0:0 :2	CIE Marks	50
Total Hours of Pedagogy L :T:P:SL:TW	0:0:28:2	SEE Marks	50
Credits	01	Total Marks	100
Type of Examination	Practical	Exam Hours	2

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1.

SET OF EXPERIMENTS

1. Study and Plot V–I Characteristics of PN Junction Diode
2. Design and Analysis of Half Wave and Full Wave Rectifier Circuits
3. Design and Performance Evaluation of Zener Diode Voltage Regulator
4. Study of BJT Characteristics in Common Emitter Configuration
5. Design of BJT as Electronic Switch and Small Signal Amplifier
6. Study of MOSFET Characteristics and Switching Operation
7. Design and Implementation of Operational Amplifier Applications (Inverting, Non-Inverting, Voltage Follower)
8. Implementation and Verification of Basic Logic Gates Logisim Evolution
9. Design and Simulation of Combinational Circuits (Adder and Subtractor) Using Logisim Evolution
10. Design and Verification of Arithmetic Circuits using Mux and Demux.
11. Realization & Verification of Truth Tables
12. Design and Simulation of Counters and Finite State Machine (FSM) for Automation Applications

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

11. Electronics Devices, David A Bell,5th Edition, Oxford University Press, ISBN-13:978-0-19-569340-9
12. Electronic Devices and Circuit Theory, Robert L. Boylestad, Louis N. Nahelsky, 11th Edition, Pearson Education, ISBN:978-93-325-4260-0
13. Digital Logic and Computer Design, M Morris Mano, Pearson Education, ISBN:978-93-325-4252-5
14. Digital Fundamentals, Thomas L. Floyd, 11th Edition, Pearson Education, 2025, ISBN: 9781292485263.

Reference books / Manuals:

14. .
15. .
16. .

Web links and Video Lectures (e-Resources):

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1.
2.

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.

Rubrics for CIE – Continuous assessment:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks.**
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment				
Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
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Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to analyze the output. (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

4th Semester syllabus Robotic and AI 2025 Scheme

Robot Kinematics and Dynamics			
Course Code	**1BRI401**	Scheme	2025
Type of Course	**PCC**	Semester	3
Teaching Hours/Week (L:T:P)	3:0 :0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42: 00: 00: 48	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. To study the direct kinematics solutions for the different robot configurations
2. To study the Inverse kinematics solutions for the different robot configurations
3. To study the Jacobian Matrix for the different robot configurations and to identify the singular configurations for different robot configurations
4. To study the dynamic equation of motion of a robot

Module-1

Forward Kinematics

Introduction to Forward Kinematics and Inverse Kinematics, 3D Homogeneous Transformations, applications of 3D homogeneous transformations to robot kinematics, Links joints and their parameters, Kinematic Modeling of the manipulator, Denavit – Hartenberg notation, Kinematic relationship between adjacent links, Direct kinematics solution for 2R Planar Manipulator, 3R Robot, Cylindrical robot, SCARA Robot, RPY Wrist.

Number of Hours: 8

Module-2

Inverse kinematics

Manipulator workspace, Solvability of inverse kinematic model, Existence of solution, Multiple solutions, Solution technique, Closed form solution, Guidelines to obtain closed form solutions, Inverse kinematic solution for2R Planar Manipulator, 3-DOF Articulated arm robot, Cylindrical robot, RPY Wrist and SCARA Robot.

Number of Hours: 8

Module-3

Manipulator Differential Motion and Statics

Linear velocity and Angular velocity of a link, Linear velocity due to angular motion, Combined linear and angular motion, Relationship between transformation matrix and angular velocity, Mapping velocity vector, Velocity propagation of a link, Angular velocity of a link, Manipulator Jacobian, Jacobian computation, The prismatic joint Jacobian, The rotary joint Jacobian, Jacobian inverse, Jacobian singularity, Computation of singularities, Wrist singularities and singular configurations, Determination of Jacobian Matrix and singular configurations for 2R robot, 3R robot

Number of Hours: 8

Module-4

Robot Dynamics

Lagrangian mechanics, Two degree of freedom manipulator – dynamic model, Lagrange – Euler formulation, Velocity of a point on the manipulator, The inertia tensor, the kinetic energy, The potential energy, Equation of motion, The LE dynamic model algorithm, Derivation of Dynamic equation of motion for 2DOF robot configuration.

Number of Hours: 8

Module-5

Robot Trajectory Planning

Definitions and planning tasks, Terminology, joint space techniques, Use of a p-Degree polynomial as interpolation function, Cubical polynomial trajectories, Linear function with parabolic blends, Cartesian space techniques, A straight –line path, A circular path, Position planning, Orientation planning, Joint-space versus Cartesian space trajectory planning, 4-3-4 Joint Trajectory planning, problems.

Number of Hours: 8

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

TEXTBOOKS:

1. Robotics and Control, R K Mithal and I J Nagrath , McGraw Hill
2. Fu, K., Gonzalez, R. and Lee, C. S. G., Robotics: Control, Sensing, Vision and Intelligence, McGraw- Hill, 2008
3. Introduction to Robotic Analysis - Niku, S.B., Systems, Applications, Pearson Education, 2008.

REFERENCE BOOKS:

1. Introduction to Robotics: Mechanics and Control- 2nd Edition - Craig, J. J., Addison-Welsey, 2nd Edition1989.
2. Fundamentals of Robotics, Analysis and Control- Schilling R. J., PHI, 2006.

Web links and Video Lectures (e-Resources):

E Books / MOOCs/ NPTEL

1. https://onlinecourses.nptel.ac.in/noc20_me53/preview
2. https://www.classcentral.com/course/swayam-mechanics-and-control-ofrobotic-manipulators-43637
3. http://vlabs.iitkgp.ac.in/mr/#https://www.isa.org/

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Software-Assisted Kinematic Visualization: Integrate computational tools like MATLAB Robotics Toolbox or RoboAnalyzer to let students dynamically vary D-H parameters and visually map out the resulting changes in a manipulator's 3D workspace.

2. Interactive Matrix Derivation Workshops: Conduct active-learning mathematical workshops where students collectively derive Forward Kinematics solutions for 2R Planar and SCARA robots, validating their theoretical matrices against physics-based simulations.

3. Simulation of Velocity Mapping and Singularities: Use software platforms to graph joint velocities and determinant values of Jacobian matrices, helping students physically visualize what happens to an arm during a "wrist singularity" configuration.

4. Algorithmic Simulation of Dynamic Models: Employ numerical computing environments to solve complex Lagrange-Euler dynamic formulations for 2-DOF manipulators, enabling students to plot structural inertia, kinetic energy, and required joint torques.

5. Interactive Trajectory Curve Generation: Direct students to program, compute, and compare cubic polynomials, 4-3-4 configurations, and Linear Functions with Parabolic Blends (LFPB) to observe real-time differences between joint-space and Cartesian-space trajectories.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks.**

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1.	Software Exploration (MATLAB or Python libraries for Robots) for simulation	20
2.	Case Study Presentation selecting any robot based on application	05

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to): - Course Project - Case Study Presentation - Programming Assignment - Tool/Software Exploration - Literature Review - Open Book Test (preferably at RBL4 and RBL5 levels) - GATE-based Aptitude Test - Assignment (at RBL3, RBL4, or RBL5 levels) - Any other relevant and innovative academic activity - Use of MOOCs and Online Platforms
Suggested Innovative Delivery Methods may include (but are not limited to): - Flipped Classroom - Problem-Based Learning (PBL) - Case-Based Teaching - Simulation and Virtual Labs - Partial Delivery of course by Industry expert/ industrial visits - ICT-Enabled Teaching - Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.		
2.		
3.		
4.	(Add rows if required)	
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.		
2.		
3.		
4.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

Object Oriented Programming

Course Code	**1BRI402**	Scheme	2025
Type of course	IPCC	Semester	IV
Teaching Hours/Week (L:T:P)	3:0:2	CIE Marks	50
Total Hours of Pedagogy L:T:P:SL:TW	42:0:28: 20:30	SEE Marks	50
Credits	4	Total Marks	100
Type of Examination (IPCC):	Theory- CIE +SEE, and Lab- CIE only.	Exam Hours	3

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **Explain** the fundamentals of object-oriented programming and essential C++ constructs required for modular engineering software development.
2. **Develop** C++ programs using classes, objects, constructors, encapsulation and composition to represent robotics and automation components.
3. **Apply** inheritance, polymorphism and operator overloading to design reusable software modules for sensors, actuators and robot-state representation.
4. **Use** file handling, exception handling and basic standard library features to process sensor readings, robot status data and automation records.
5. **Design and demonstrate** a simple object-oriented C++ application for a robotics or automation problem with proper class structure, testing and documentation.

Module-1

Principles of Object-Oriented Programming: Object-oriented programming paradigm; Basic concepts of object-oriented programming; Applications of object-oriented programming.
Beginning with C++: What is C++; Applications of C++; A simple C++ program; Structure of a C++ program; Creating the source file; Compiling and linking.
Tokens, Expressions and Control Structures: Tokens; Keywords; Identifiers and constants; Basic data types; User-defined data types; Derived data types; Declaration of variables; Reference variables; Operators in C++; Expressions and their types; Operator precedence; Control structures.

Functions in C++: Function prototyping; Call by reference; Return by reference; Inline functions; Default arguments; Const arguments; Function overloading.

Textbook - 1: Ch 1,2,3,4 (*Selected Topics only*) **Number of Hours: 08**

Module-2

Classes, Objects, Constructors and Encapsulation

Classes and Objects: C Structure Revisited; Specifying a Class; Defining Member Functions; A C++ Program with Class; Making an Outside Function Inline; Nesting of Member Functions; Private Member Functions; Arrays within a Class; Memory Allocation for Objects; Static Data Members; Static Member Functions; Arrays of Objects; Objects as Function Arguments; Friendly Functions; Returning Objects; const Member Functions.

Constructors and Destructors: Constructors; Parameterized Constructors; Multiple Constructors in a Class; Constructors with Default Arguments; Dynamic Initialization of Objects; Copy Constructor; const Objects; Destructors.

Textbook - 1: Ch 5,6 (*Selected Topics only*) **Number of Hours: 08**

Module-3

Standard Library Containers and Object Collections

Strings, Vectors, and Arrays: Library string Type; Library vector Type; Introducing Iterators; Arrays.

Sequential Containers: Overview of the Sequential Containers; Container Library Overview; Sequential Container Operations: Adding Elements to a Sequential Container, Accessing Elements, Erasing Elements, Specialized forward_list Operations, Resizing a Container; Container Adaptors.

Associative Containers: Using an Associative Container; Overview of the Associative Containers; Operations on Associative Containers.

Textbook - 2: Ch. 3, Ch. 9 and Ch. 11(*Selected Topics only*)
Number of Hours: 08

Module-4

Operator Overloading, Inheritance and Polymorphism

Operator Overloading and Type Conversions: Defining Operator Overloading; Overloading Unary Operators; Overloading Binary Operators; Overloading Binary Operators using Friend Functions; Rules for Overloading Operators; Type Conversions.

Inheritance: Defining Derived Classes; Single Inheritance; Making a Private Member Inheritable; Multilevel Inheritance; Multiple Inheritance; Hierarchical Inheritance; Hybrid Inheritance; Virtual Base Classes; Abstract Classes; Constructors in Derived Classes.

Pointers, Virtual Functions and Polymorphism: Pointers; Pointers to Objects; this Pointer; Pointers to Derived Classes; Virtual Functions; Pure Virtual Functions.

Textbook - 1: Ch. 7, Ch. 8 and Ch. 9 (*Selected Topics only*) **Number of Hours: 08**

Module-5

Error Handling, File I/O, Templates and Generic Algorithms

Basic Exception Handling: try Blocks and Exception Handling.
Enumerations: Enumerations.
File Input and Output: The IO Classes; File Input and Output; string Streams.
Templates and Generic Programming: Defining a Template; Template Argument Deduction.

Textbook - 2: Ch. 5, Ch. 19, Ch. 8, Ch. 16 *(Selected Topics only)*

Number of Hours: 08

PRACTICAL COMPONENTS OF IPCC

FIXED SET OF EXPERIMENTS

1. Develop a C++ program to calculate basic robot motion parameters such as distance, speed and time. Demonstrate function prototyping, call by reference, inline function, default arguments and function overloading.
2. Develop a C++ program to create a Robot class with data members such as robot ID, robot name, robot type, payload capacity and battery level. Use member functions to read and display robot details.
3. Design a Sensor class with sensor ID, sensor type, measurement unit and current reading. Use default constructor, parameterized constructor and copy constructor to initialize and display sensor details.
4. Implement a Motor class with speed, torque and direction as private data members. Use public member functions to set and display motor values. Validate unsafe values such as negative speed and speed beyond the allowed limit. Use a friend function to compare the torque of two motors.
5. Develop a C++ program to store and display details of multiple sensors using an array of objects. Include sensor ID, sensor type and current reading. Identify the sensor with the highest reading.
6. Design a MobileRobot class using composition by including objects of Battery and Motor classes. Display the complete status of the mobile robot including battery percentage and motor speed.

7. Develop a C++ program to store sensor names and readings using string and vector. Use iterators to display the stored sensor details and compute the average sensor reading.
8. Develop a C++ program to manage robot tasks using standard library containers. Use queue to store pending robot tasks and map to store robot ID with its current status.
9. Create a RobotPose class with x-position and y-position. Overload the + operator to update robot position and overload a comparison operator to compare two robot positions.
10. Implement inheritance using a base class Sensor and derived classes such as UltrasonicSensor and TemperatureSensor. Demonstrate how derived classes reuse and extend the base class features.
11. Create a base class Actuator with a virtual function operate(). Derive classes such as ServoMotor and Gripper and override the function to display actuator-specific operation.
12. Develop a C++ program to write sensor readings into a text file and read them back. Use an enumeration to represent robot states such as IDLE, MOVING, STOPPED and ERROR. Use a function template to process readings of different data types. Apply basic exception handling for file-opening failure or invalid input. Use any one read-only generic algorithm such as count, find or max_element.

Note: The course shall preferably be implemented using **Modern C++ with C++17 or later**. Students shall be encouraged to use standard library features such as string, vector, containers, iterators, file streams, templates and exception handling. C-style strings and outdated C-style programming practices may be avoided except for basic comparison wherever required.

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. E. Balagurusamy, "*Object-Oriented Programming with C++*", 8th Edition, McGraw Hill Education, 2021.
2. Stanley B. Lippman, Josée Lajoie and Barbara E. Moo, "*C++ Primer*", 5th Edition, Addison-Wesley / Pearson, 2012.

Reference Books / Manuals

1. Robert Lafore, Object-Oriented Programming in C++, 4th Edition, Sams Publishing / Pearson.
2. Bjarne Stroustrup, Programming: Principles and Practice Using C++, 2nd Edition, Addison-Wesley.
3. Department Laboratory Manual for Object Oriented Programming for Robotics and Automation.

Web links and Video Lectures (e-Resources):

1. **cppreference –** C++ Reference: for C++ language features, STL containers, algorithms, input/output library and exceptions.
2. **LearnCpp –** Modern C++ Tutorials: for classes, constructors, inheritance, virtual functions, polymorphism, templates and STL.
3. **NPTEL / SWAYAM –** Object-Oriented Programming / Programming in C++: for structured video-based learning.
4. **ROS2 Documentation –** C++ Publisher and Subscriber Tutorials: for optional exposure to C++ usage in robotic software architecture.
5. **GeeksforGeeks C++ STL and OOP Practice Resources:** for additional programming practice and problem-solving.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. *Concept demonstration through domain examples:* Core OOP concepts such as class, object, constructor, encapsulation, inheritance and polymorphism will be explained using simple examples from robotics and automation, such as Robot, Sensor, Motor, Battery, Actuator and RobotPose.
2. *Problem-based programming practice:* Students will be given small programming tasks related to robot information handling, motor speed validation, sensor monitoring, position update and actuator operation. This will help them understand how C++ programs can be structured for engineering applications.
3. *Design before coding:* For selected problems, students will first identify the required classes, data members and member functions. Simple class diagrams may be used before writing the C++ program so that students develop a habit of planning the solution.
4. *Case-based discussion:* Basic cases such as mobile robot movement, robotic arm status display, conveyor belt operation and warehouse robot task assignment may be discussed to show how object-oriented design supports modularity and code reuse.
5. *Code review and debugging practice:* Students will be guided to check access specifiers, constructor usage, class relationships, overridden functions, file handling and output correctness. This will improve programming discipline and reduce common implementation mistakes.
6. *Mini-project-based learning:* Towards the end of the course, students will develop a simple console-based C++ application related to robotics or automation by combining the concepts learned in the theory and laboratory sessions.

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE Theory component will be **25 marks** and CIE Practical component will be **25 marks**.

The CIE Theory component consists of IA tests for 25 marks. The CIE Practical component for continuous assessments will be for 15 marks through rubrics and for lab tests will be for 10 marks.

- To qualify and become eligible to appear for SEE, in the **CIE theory component**, a student must score at least **40% of 25 marks**, i.e., **10 marks**.
- To qualify and become eligible to appear for SEE, in the **CIE Practical component**, a student must secure **a minimum of 40% of 25 marks**, i.e., **10 marks.**
- To pass the **SEE**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

CIE Practical component:

The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. The summation of all the experiments marks to be scaled down to 15 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and scaled down to 10 marks. For laboratory test, the student is required to conduct one experiment.

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):
Suggested Learning Activity: Programming Assignment / UML-to-Code Activity / Case Study / Mini Application
Maximum Marks: 10

Performance Indicator	Superior	Good	Fair	Needs Improvement	Unacceptable
Problem Understanding and Domain Relevance – 2 Marks CO1, CO2 / PO1, PO2	Clearly understands the given problem and relates it appropriately to robotics or automation. **2**	Understands the problem with a reasonable domain connection. **1.5**	Shows basic understanding, but the domain connection is limited. **1**	Problem understanding is weak and domain relevance is unclear. **0.5**	Problem is not understood or not relevant. **0**
Object-Oriented Design – 3 Marks CO2, CO3 / PO2, PO3	Identifies suitable classes, data members, member functions and relationships with proper OOP design. **3**	Class design is mostly appropriate with minor omissions. **2.5**	Basic class design is present, but relationships are not clear. **1.5–2**	Design is incomplete and shows limited OOP understanding. **1**	No proper object-oriented design is presented. **0**
Implementation / Activity Execution – 2 Marks CO3, CO4 / PO3, PO5	Program/activity is completed correctly with proper logic and execution. **2**	Program/activity is mostly correct with minor errors. **1.5**	Program/activity is partially completed and works for limited cases. **1**	Implementation has major logical or execution errors. **0.5**	No meaningful implementation is done. **0**
Testing, Output and Analysis – 2 Marks CO4 / PO4	Suitable test cases are used and the output is clearly interpreted. **2**	Common test cases are used and output is explained. **1.5**	Limited testing is done with basic output explanation. **1**	Output is shown, but testing and analysis are inadequate. **0.5**	Output is missing, incorrect or not explained. **0**
Documentation and Presentation – 1 Mark CO5 / PO10, PO12	Work is neatly documented and explained clearly. **1**	Documentation is mostly complete with satisfactory explanation. **0.75**	Documentation is basic and explanation has gaps. **0.5**	Documentation is incomplete and explanation is weak. **0.25**	Documentation is absent or student is unable to explain. **0**
				Total	**10 Marks**

Rubrics for CIE – Continuous assessment:

Performance Indicator	Superior	Good	Fair	Needs Improvement	Unacceptable
Understanding of Problem and OOP Concept – 4 Marks CO1 / PO1	Clearly understands the problem statement and identifies the required OOP concept. **4**	Understands the problem and concept with minor gaps. **3**	Shows basic understanding, but explanation lacks clarity. **2**	Has limited understanding of the problem or concept. **1**	Does not understand the problem or concept. **0**
Class Design / Algorithm / Logic – 6 Marks CO2, CO3 / PO2, PO3	Designs suitable classes, data members, member functions and relationships with proper logic. **6**	Design and logic are mostly correct with minor omissions. **5**	Basic design is present, but class relationships or logic are incomplete. **3–4**	Design is weak and shows limited use of OOP principles. **1–2**	No proper design or logic is presented. **0**
Program Implementation – 8 Marks CO2, CO3, CO4 / PO3, PO5	Program is correct, modular, readable and uses the required OOP concept properly. **7–8**	Program is mostly correct with minor syntax or logical errors. **5–6**	Program is partially correct and executes with limitations. **3–4**	Program is incomplete or has major errors. **1–2**	Program is not implemented or does not execute. **0**
Execution, Output and Testing – 5 Marks CO4 / PO4	Program executes correctly for different test cases; output is verified and interpreted properly. **5**	Program executes for common test cases with correct output. **4**	Program executes for limited cases with basic output verification. **3**	Output is obtained, but testing and interpretation are inadequate. **1–2**	Output is missing or incorrect. **0**
Laboratory Record / Documentation – 4 Marks CO5 / PO10	Record is complete with aim, class design/algorithm, program, output and conclusion. **4**	Record is mostly complete with minor omissions. **3**	Record is partially complete but understandable. **2**	Record is incomplete or poorly organized. **1**	Record is not submitted. **0**
Viva-Voce / Explanation – 3 Marks CO1, CO5 / PO10, PO12	Student explains the program, logic, output and OOP concept clearly. **3**	Student explains most parts with minor gaps. **2**	Student gives a basic explanation. **1**	Student is unable to explain properly. **0.5**	Student does not answer. **0**
				Total	**30 Marks**

Rubrics for SEE / CIE Test:

Question-wise Evaluation Rubric

Marks may be applied proportionately based on the marks allotted to each question.

Performance Indicator	Superior	Good	Fair	Needs Improvement	Unacceptable

Conceptual Understanding CO1 / PO1	Provides accurate explanation of the concept with correct terminology and relevant examples. **80–100% of allotted marks**	Explanation is mostly correct with minor gaps. **60–79% of allotted marks**	Basic explanation is given, but clarity and depth are limited. **40–59% of allotted marks**	Explanation is incomplete or partially incorrect. **20–39% of allotted marks**	Explanation is incorrect or not attempted. **0–19% of allotted marks**
Application of OOP Concepts CO2, CO3 / PO2, PO3	Applies classes, objects, inheritance, polymorphism or related OOP concepts correctly to the given problem. **80–100% of allotted marks**	Applies the required concept with minor errors. **60–79% of allotted marks**	Applies basic concepts but misses important details. **40–59% of allotted marks**	Application is weak or mostly incorrect. **20–39% of allotted marks**	No relevant application is shown. **0–19% of allotted marks**
Program Logic / Class Design CO2, CO3, CO4 / PO3, PO5	Presents correct logic, suitable class design and proper sequence of steps. **80–100% of allotted marks**	Logic and class design are mostly correct with minor issues. **60–79% of allotted marks**	Partial logic is present, but class design is incomplete. **40–59% of allotted marks**	Logic has major gaps and design is unclear. **20–39% of allotted marks**	No proper logic or design is presented. **0–19% of allotted marks**
Code Correctness / Output Interpretation CO3, CO4 / PO4, PO5	Code is syntactically and logically correct, and output is interpreted properly. **80–100% of allotted marks**	Code is mostly correct with minor errors. **60–79% of allotted marks**	Code is partially correct and output explanation is limited. **40–59% of allotted marks**	Code contains major errors or output is not properly explained. **20–39% of allotted marks**	Code is absent, irrelevant or incorrect. **0–19% of allotted marks**
Presentation of Answer CO5 / PO10, PO12	Answer is neat, well-structured and technically clear. **80–100% of allotted marks**	Answer is clear with minor presentation issues. **60–79% of allotted marks**	Answer is understandable but not well organized. **40–59% of allotted marks**	Answer is poorly organized and difficult to follow. **20–39% of allotted marks**	Answer is unreadable, irrelevant or not attempted. **0–19% of allotted marks**
				Total	**50 Marks**

Suggested rubrics for Practical continuous assessment:

Performance Indicators	Excellent	Very Good	Good	Satisfactory
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyse the output (3)	Student will be able to run the program but not able to analyse the output (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.	Programming assignment on modelling basic robotics components such as Robot, Sensor, Motor and Battery using classes and objects.	6
2.	UML class diagram preparation and C++ implementation for a mobile robot, robotic arm, conveyor system or sensor monitoring application.	8
3.	Case study presentation on object-oriented software design used in robotics or automation systems.	6
4.	Mini project development, testing, demonstration and report submission based on a console-based robotics or automation application.	10
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	Self-study of C++ classes, constructors, inheritance and polymorphism using textbooks, NPTEL lectures or spoken tutorials.	5
2.	Practice on arrays of objects, file handling and basic standard library containers for storing robot or sensor data.	5
3.	Study and practice of exception handling and input validation for simple automation-oriented programs.	4
4.	Preparation of mini-project design document, sample input/output, testing table and code review checklist.	6

Continuous Internal Evaluation (CIE)

(i)Theory component

The CIE marks of 25 shall be earmarked for two tests.

The first test shall be conducted after completing two modules of the syllabus and the second one after completing the rest three modules.

Each test shall be conducted for 25 marks. The average of the two tests scaled down to 25 marks shall constitute the test marks for a maximum of 25 marks.

(ii) Laboratory component

Out of 25 marks, 15 marks shall be assigned for assessment as per the rubrics listed in the course syllabus.
The remaining 10 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for regular class work and practical test as indicated in the Table – ICs/IPCCs 1.
(i) To qualify and become eligible to appear for the SEE of the IC/IPCC, a student shall secure at least 40 % of 25 marks, i.e., 10 marks, in the CIE theory component, and at least 40 % of 25 marks, i.e., 10 marks in the CIE Practical component.

Passing requirement in SEE

Table – ICs/IPCCs 1 Distribution of marks		
Component	**Description**	**Marks**
Allotment of marks for regular class work		
Ability in Conducting Experiments	Initiative, skill, safety practices, teamwork, and independent handling of equipment during regular lab sessions.	5 marks
Laboratory Record / Journal	Regular and neat maintenance of lab record, accuracy of results, and timely submission.	10 marks
	Subtotal	**15**
Allotment of marks for CIE practical test		
Laboratory Test / Experiment Performance	Ability to set up apparatus, follow procedure, take observations, and obtain correct results in the test experiment.	5 marks
Viva-Voce	Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.	5 marks
	Subtotal	**10**
	Total	**25**

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

CONTROL ENGINEERING			
Course Code	**1BRI403**	Scheme	2025
Type of Course	**Professional Core Course**	Semester	4
Teaching Hours/Week (L:T:P)	3: 1: 0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42 : 28 : 00 : 50	SEE Marks	50
Credits	**04**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)
At the end of the course, the student will be able to:
CO1: Explain the fundamentals of control systems and develop mathematical models and representations of engineering systems using transfer functions, block diagrams, and signal flow graphs.

CO2: Analyse the time-domain performance of control systems by determining transient response characteristics, steady-state errors, and the effects of feedback on system accuracy and sensitivity.

CO3: Evaluate the stability and frequency response characteristics of control systems using Routh-Hurwitz criterion, root locus techniques, Bode plots, and Nyquist stability criterion.

CO4: Formulate and analyse state-space and basic bond graph models of dynamic systems and assess controllability and observability.

Module-1

Basics of Control Systems

Introduction to control systems
Definition of control system, Need for and importance of control systems, Examples of control systems in mechanical engineering, Liquid level control system, Temperature control system, Speed control system, Basic components of a control system, Block diagram of a control system, Input, output, controller, plant, actuator, sensor, and feedback element.

Types and Components of Control Systems
Open-loop control system, Closed-loop control system, Comparison between open-loop and closed-loop control systems, Advantages and disadvantages of feedback, Common sensors and actuators used in industrial control systems, Use of relays, switches, and contactors, Brief introduction to logic-based and sequential control systems.

Number of Hours: 10

Module-2

Mathematical Modelling and System Representation:

Mathematical Modelling of Systems
Need for mathematical modelling, Differential equation model of simple systems, Mechanical systems - Translational system, Rotational system, Mass-spring-damper system, Electrical systems - R, L, and C elements, Simple RLC circuit, Basic thermal and hydraulic systems, Transfer function concept, Poles and zeros of transfer function.

Block Diagram and Signal Flow Graph
Open-loop and Closed-loop transfer functions, Rules of block diagram algebra, Simple block diagram reduction, Signal flow graph, Basic terms in signal flow graph, Mason's gain formula, Simple problems.

Number of Hours: 08

Module-3

Time-Domain Analysis

Time Response of Systems
Introduction to time-domain analysis, Standard test signals: -Step input, Ramp input, Impulse input, First-order system response, Second-order system response, Transient response and steady-state response, Time response specifications - Rise time, Peak time, Maximum overshoot, Settling time.

Steady-State Error and Effect of Feedback

Steady-state error, Type of system, Position, velocity and acceleration error constants, Steady-state error for step, ramp and parabolic inputs, Sensitivity and effect of parameter variations, Effect of feedback on - Stability, Accuracy, Disturbance rejection, Simple numerical problems.

Number of Hours: 08

Module-4

Stability and Frequency-Domain Analysis

Stability Analysis

Meaning of stability, Stable, unstable, and marginally stable systems, Effect of pole location on stability, Routh-Hurwitz stability criterion, Construction of Routh array, Simple problems on Routh-Hurwitz criterion, Root locus technique, construction rules and effect of gain variation, Stability analysis using root locus.

Frequency-Domain Analysis

Introduction and need for frequency-domain analysis, Bode plot basics, Magnitude plot and phase plot, Gain margin and phase margin, Frequency-domain specifications, Introduction to Nyquist stability criterion (conceptual treatment only, no numerical problems), Correlation between time-domain and frequency-domain response.

Number of Hours: 08

Module-5

State-Space Approach

State-Space Representation and Bond Graph Modeling

Need for state-space representation in modern control systems; state variables, state equations, simple state-space models of mechanical and electromechanical systems; introduction to bond graphs and their use in modeling engineering and mechatronic systems.

State-Space Analysis and Control

Basic analysis of state-space models; eigenvalues, state transition matrix, controllability and observability; introduction to state feedback control and applications in servo systems, DC motors and mechatronic systems.

Number of Hours: 08

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. **Modern Control Engineering, Katsuhiko Ogata, 5th Edition, Pearson Education, New Delhi, 2010.**
2. **Control Systems Engineering, Norman S. Nise, 8th Edition, Wiley India Pvt. Ltd., New Delhi, 2020.**
3. **Automatic Control Systems, Benjamin C. Kuo and Farid Golnaraghi, 10th Edition, Wiley India Pvt. Ltd., New Delhi, 2017.**

<u>**Reference Books**</u>

1. **Control Systems Engineering, I. J. Nagrath and M. Gopal, *Control Systems Engineering*, 7th Edition, New Age International Publishers, New Delhi, 2021.**
2. **Feedback Control of Dynamic Systems, Gene F. Franklin, J. David Powell and Abbas Emami-Naeini, 8th Edition, Pearson Education, New Delhi, 2019.**
3. **Modern Control Systems, Richard C. Dorf and Robert H. Bishop, 13th Edition, Pearson Education, New Delhi, 2017.**
4. **Control Systems, A. Anand Kumar, 2nd Edition, PHI Learning Pvt. Ltd., New Delhi, 2014.**
5. **Control Systems: Principles and Design, M. Gopal, 5th Edition, McGraw Hill Education (India) Pvt. Ltd., New Delhi, 2021.**

Web links and Video Lectures (e-Resources):

1. **NPTEL Control Systems – IIT Madras: Useful for complete syllabus coverage: Introduction, transfer function, time response, Routh criterion, root locus, Bode plot, Nyquist plot, and state-space analysis.** **nptel.ac.in/courses/108106098**

2. **SWAYAM / NPTEL Control Systems Course: Structured 12-week course suitable for undergraduate engineering students.** **https://onlinecourses.nptel.ac.in/e-learning/preview/noc20_ee90**

3. **MATLAB Control System Toolbox Tutorials: Useful for simulation of transfer functions, step response, Bode plots, root locus, Nyquist plots, and state-space models.** **https://uk.mathworks.com/products/control.html**

4. **Control Tutorials for MATLAB and Simulink – Root Locus: Useful for learning root locus design with simple MATLAB examples.** **https://ctms.engin.umich.edu/CTMS/index.php?example=Introduction&section=ControlRootLocus**

5. **Control Tutorials for MATLAB and Simulink – Suspension System Example: Useful for mechanical engineering students to understand control application in vehicle suspension systems.** **https://ctms.engin.umich.edu/CTMS/index.php?example=Suspension&section=ControlRootLocus**

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. **Simulation-Based Learning:** Use MATLAB/Scilab/Python tools for modelling, time-response analysis, stability assessment, and state-space representation.
2. **Case Study-Based Learning:** Analyze real-world control systems such as temperature control, water-level control, cruise control, and robotic actuators.
3. **Problem-Based Learning:** Solve open-ended engineering problems involving transfer functions, stability analysis, and feedback system design.
4. **Flipped Classroom and Collaborative Learning:** Utilize NPTEL/SWAYAM resources for pre-class learning followed by group discussions, problem-solving, and concept presentations in class.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
01	Identify open-loop and closed-loop control systems from real-life applications such as water level control, temperature control, cruise control, and robotic actuators. Prepare block diagrams showing controller, actuator, sensor, plant, and feedback elements.	25

Performance Indicator (CO/PO Mapping)	Superior	Good	Fair	Needs Improvement	Unacceptable
Identification and classification of control systems (CO1/PO1)	Correctly identifies and classifies all systems as open-loop or closed-loop with clear justification.	Correctly identifies most systems with minor errors in classification.	Correctly identifies some systems but justification is incomplete.	Identifies only a few systems correctly.	Unable to distinguish between open-loop and closed-loop systems.
Identification of control system components (CO1/PO1, PO2)	Accurately identifies controller, actuator, sensor, plant, input, output, and feedback elements for all systems.	Identifies most components correctly with minor omissions.	Identifies basic components but misses several important elements.	Identifies only a few components correctly.	Unable to identify system components.
Preparation of block diagrams (CO1/PO2)	Constructs complete and accurate block diagrams using standard control system notation.	Constructs block diagrams with minor errors.	Constructs basic block diagrams but with noticeable errors.	Diagrams are incomplete and difficult to interpret.	Unable to prepare meaningful block diagrams.
Understanding of feedback concept and system operation (CO1/PO1)	Clearly explains system operation and the role of feedback in each application.	Explains system operation with minor conceptual gaps.	Demonstrates partial understanding of feedback concepts.	Limited understanding of system operation and feedback.	Unable to explain the role of feedback.
Technical communication and presentation	Information is well organized, clearly presented, and	Presentation is clear with minor deficiencies.	Adequate presentation but lacks clarity or	Poorly organized presentation with incomplete	Unable to communicate ideas effectively.

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
5.	Assignments and tutorial exercises	Considering planning, preparation and execution student to spend about 25 hours on any one or combination of term work activity.
6.	Seminar/Case study presentation	
7.	Simulation-based learning activities	
8.	Micro project	
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
5.	**Self-Learning component:** NPTEL/SWAYAM courses, MOOCs, Spoken Tutorials (Scilab/MATLAB/Python), MIT Open Courseware, CTMS, MathWorks resources, and self-directed study of modelling, time-response, stability, and state-space analysis of control systems.	About 25 Hours of self-learning

Continuous Internal Evaluation (CIE)

1. The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
2. Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
3. The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

4. A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

1. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

2. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

3. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

Sensors and Actuators			
Course Code	**1BRI404**	Scheme	2025
Type of Course	**PCC**	Semester	3
Teaching Hours/Week (L:T:P)	3:0 :0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42: 00: 00: 48	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

5. Explain the structural elements, characteristics, and error behaviors of generalized measurement systems.
6. Apply the working principles of physical and digital sensors to measure real-world engineering parameters.
7. Analyze analog signal conditioning blocks, bridge balancing networks, and discrete sampling processes.
8. Design functional fluid power, electro-pneumatic sequencing, and electrical motor actuator control circuits.

Module-1

Measurements and measuring systems: Methods of Measurement-Instruments-Classification of Instruments-Functions of instruments and measurement Systems-Elements of a generalized measurement system. Measurement system performance: Static characteristics- Dynamic characteristics. Errors in measurement and their statistical analysis.

Fluid power system: Basic components, advantages, limitations and applications. Transmission of power at static and dynamic states, Pascal's law.

Number of Hours: 8

Module-2

Sensors/Transducers: Definition, Types, Basic principle and applications. Potentiometers - Inductance transducers - Capacitance transducers - Piezoelectric transducers - Hall effect transducers - rotary encoders – Accelerometers – Gyroscope. Photo Diode/ Photo Transistor as sensors, LVDT, Strain Gauge, Tactile, IR and Ultrasonic sensors. Vision and motion Sensors. **Digital transducers**: Principle and Construction. Temperature, Flow, velocity, pressure, displacement, position, force and torque measurement.

Module-3

Signal Conditioning: Need for pre-processing, identification of signal conditioning blocks and their characteristics. Analysis of DC and AC bridges. Offset and drift compensation circuits. Introduction to Active filters. First order, Second order and higher order filters. Necessity and applications of isolation amplifiers, Grounding and Shielding. **Digital Signal Processing**: Discrete Sequences and Systems, Periodic Sampling, Discrete Fourier Transform, Fast Fourier Transform. Analog to digital conversion. Number of Hours: 8
Module-4
Pneumatic Actuators and Hydraulic Linear Actuator types - Single acting and Double Acting cylinder. Rotary Actuator types - gear, vane, screw, piston types. Symbols for pneumatic, hydraulic and electropneumatic. **Electrical actuators**: Introduction to Electrical actuators, Solenoids, Rotating electrical machines, operating principles, main terminology and industrial standards. DC, Synchronous, Induction, Stepper, BLDC, Servo motor: principle of operation, main characteristics and construction, Types, Starting, Speed Control and braking, Efficiency, Testing, Selection considerations. Number of Hours: 8
Module-5
Hydraulic Circuit Design: Control of single and Double -acting hydraulic cylinder, hydraulic cylinder sequencing circuits, speed control of hydraulic cylinder- metering in, metering out and bleed off circuits. **Pneumatic and Electro-Pneumatic Circuit Design**: Single cylinder application: Direct and indirect actuation pneumatic cylinders, speed control of cylinders - supply air throttling and exhaust air throttling. Electro- Pneumatic Control: Principles - signal input and output, pilot assisted solenoid control of DCV's, use of relay and contactors. Number of Hours: 8

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Doebelin, E.O. and Manic, D.N., "Measurement Systems: Applications and Design", 7th Edition, McGraw Hill, 2019.
2. Richard G. Lyons, "Understanding Digital Signal Processing", 3rd Edition, Pearson, 2011.
3. A.K. Sawhney, "A Course in Electronic Measurements and Instrumentation", Dhanpat Rai & Co. (P) Limited, 2015.
4. Pneumatics and Hydraulics, Andrew Parr, Jaico Publishing Co, 1993
5. S. R. Deb; Sankha Deb. Robotics Technology and Flexible Automation, Second Edition McGraw-Hill Education: New York, 2010.
6. Kothari D.P. and Nagrath I.J., "Electric Machines", Tata McGraw-Hill Publishing Company Limited, New Delhi, 2004.
7. Gopal K. Dubey, Fundamentals of Electrical Drives, Narosa Publishing House, 2016

Reference books / Manuals:

1. Murthy, D.V.S., "Transducers and Instrumentation", 2nd Edition, Prentice Hall of India, 2011.
2. Pillay. S.K, A First Course on Electric Drives, Wilely Eastern Limited, Bombay, 2012
3. Stephen J. Chapman, 'Electric Machinery Fundamentals'4th edition, McGraw Hill Education Pvt. Ltd, 2010.
4. Jagadeesha T., "Hydraulics and Pneumatics", 1st edition, I K International Publishing House, New Delhi, 2015

WNPTEL / SWAYAM Video Lectures:

- Industrial Instrumentation / Sensors and Actuators (IIT Kharagpur / IIT Madras): Highly recommended series covering generalized measurement systems, sensor static/dynamic characteristics (Module 1), and deep-dives into transducers like LVDT, strain gauges, and encoders (Module 2).
- Fluid Power Systems: Comprehensive video library for understanding Pascal's law, hydraulic/pneumatic cylinder configurations, and ISO symbols (Module 1 & 4).
- Interactive Circuits & Simulation Tools:
- Automation Studio / FluidSIM (Easiest Learning Tools): Crucial digital platforms to design, animate, and test fluid power systems, sequencing circuits, and electro-pneumatic relay logic (Module 5).
- Falstad / LTspice Circuit Simulators: Excellent online tools for visualizing signal conditioning blocks, bridge balancing (AC/DC), operational amplifier offsets, and active filter frequency responses (Module 3).

Technical Datasheets and Digital Handbooks:

Texas Instruments / Analog Devices App Notes: Practical reference links detailing signal isolation, grounding techniques, shielding methods, and ADC sampling constraints (Module 3).eb links and Video Lectures (e-Resources):

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Block-Diagram Mapping of Real Instruments: Instruct students to dissect everyday or laboratory instruments to trace and sketch their core structural layout, explicitly identifying the sensor, signal conditioning unit, and final data presentation element.
2. Live Sensor Calibration Exercises: Organize physical demonstrations using data acquisition setups where students plot the response curves of devices like LVDTs, ultrasonic sensors, or strain gauges to calculate real-world static properties like linearity, sensitivity, and hysteresis.
3. Software-Based Filter and Bridge Testing: Use electronic simulation environments to let students build Wheatstone bridges and active filters, observing how changing component variables impacts noise attenuation, drift compensation, and frequency response curves.
4. Interactive Symbol Matching and Actuator Testing: Utilize digital design boards or actual cutout components to train students in recognizing standard ISO fluid power symbols, pairing them directly with physical DC, stepper, and servo motor hardware configurations.
5. Virtual Fluid Power Circuit Prototyping: Implement software tools like FluidSIM to let students safely build, modify, and simulate sequencing, metering-in, metering-out, and electro-pneumatic relay control loops before moving onto physical laboratory test benches.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks.**

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
3.		
4.		

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in

Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
9.		
10.		
11.		
12.	(Add rows if required)	
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
6.		
7.		
8.		
9.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Sensors and Actuators Laboratory		Scheme	2025
Course Code	**1BRIL405**	Semester	3
Teaching Hours/Week (L:T:P)	0:0:2	CIE Marks	50
Total Hours of Pedagogy L:T:P:SLTW	0:0:28:2	SEE Marks	50
Credits	1	Total Marks	100
Examination type (SEE)	**Practical**	Exam Hours	2

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

9. Analyze the performance and characteristics of inertial, vision-based, and proximity sensors for engineering applications.
10. Design, construct, and evaluate signal conditioning circuits including data converters, active filters, and bridges.
11. Build and analyze fluid power circuits for the controlled actuation and sequencing of hydraulic and pneumatic systems.
12. Formulate and implement digital signal processing techniques via open-ended experimentation on embedded platforms.

Note:

1. The laboratory syllabus consists of PART-A and PART-B. While PART-A has 6 conventional experiments, PART-B has 6 typical open-ended experiments. The maximum marks for the laboratory course are 100.
2. Both PART-A and PART-B are considered for CIE and SEE.
3. Students have answer 1(one) question from PART-A and 1(one) question from PART-B.
   a. The questions set for SEE shall be from among the experiments under PART-A. It is evaluated for **70 marks** out of the maximum 100 marks.
   b. The open-ended question set for SEE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for **30 marks.**
4. For Continuous Internal Evaluation (CIE) during the semester, classwork shall typically include open-ended questions from **Part-B**, along with other similar questions designed to enhance the students' skills.

PART – A
FIXED SET OF EXPERIMENTS

1. Study of accelerometer, gyroscope and Vision based sensing
2. Ultrasonic, IR and Hall effect sensor-based proximity and range sensing
3. Analog to digital and digital to analog conversion.
4. Experimentation with Active Filters
5. Construction and analysis of Hydraulic circuit for actuation and control of single and double acting cylinders.
6. Construction and analysis of Pneumatic circuit for actuation and control of single and double acting cylinders.

PART – B
OPEN ENDED EXPERIMENTS

Open-ended experiments are a type of laboratory activity where the outcome is not predetermined and students are given the freedom to explore, design, and conduct the experiment based on the problem statements as per the concepts defined by the course coordinator. It encourages creativity, critical thinking, and inquiry-based learning.

1. Experimentation with AC and DC bridge using discrete components
2. Implementation of convolution and digital filters (Can be done with Raspberry Pi on any analog signal acquired using ADC)
3. Fourier Transforms (Can be done with Raspberry Pi on any analog signal acquired using ADC)
4. Construction and analysis of Hydraulic circuit for sequencing of two hydraulic cylinders using sequence valves.
5. Construction and analysis of Pneumatic circuit for sequencing of two pneumatic cylinders using sequence valves
6. Construction and analysis of Pneumatic circuit for controlled actuation and control of single and double acting cylinders.

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

Reference books / Manuals:

5. **"Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering" by *W. Bolton* (Pearson Education)**
6. **"Introduction to Mechatronics and Measurement Systems" by *David G. Alciatore* (McGraw-Hill).**
7. **"Fluid Power with Applications" by *Anthony Esposito* (Pearson Education).**
8. **"Design with Operational Amplifiers and Analog Integrated Circuits" by *Sergio Franco* (McGraw-Hill).**
9. **"Digital Signal Processing: Principles, Algorithms, and Applications" by *John G. Proakis and Dimitris G. Manolakis* (Pearson).**
10. **"Raspberry Pi Cookbook: Software and Hardware Problems and Solutions" by *Simon Monk* (O'Reilly Media).**

Web links and Video Lectures (e-Resources):

NPTEL / SWAYAM Video Lectures:

- ***Sensors and Actuators / Industrial Instrumentation (IIT Kharagpur / IIT Bombay):* Highly recommended online video playlists for reviewing physical setups of active filters, encoders, IMUs (accelerometer/gyroscope), and signal-conditioning instrumentation bridges.**
- ***Fluid Power Control:* Ideal instructional modules for learning standard ISO fluid schematic architectures, directional control valves, and sequence valve operational dynamics.**
- **Virtual Labs & Software Simulators:**
- ***Festo FluidSIM / Automation Studio:* Essential software resources used to pre-build, map out, and simulate complex hydraulic/pneumatic sequencing and throttling loops before handling physical laboratory manifold benches.**
- ***Virtual Labs (V-Lab) India - Electronics & Communications:* Excellent digital laboratory setups for conducting remote experiments on active filters, ADC/DAC conversion modules, and bridge balance conditions.**

Open-Source Embedded System Documentation:

- ***Raspberry Pi Foundation & Python SciPy Libraries:* Web documentation and reference code for reading SPI/I2C sensor inputs (like ADCs) and programming fast Fourier transforms (FFT) or digital filters on discrete signal streams.**

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

13. Pre-Lab Software Verification Blocks: Mandate students to model and simulate all pneumatic and hydraulic circuits (such as directional and sequencing loops) in virtual simulation environments like FluidSIM prior to building them on physical hardware benches.

14. Embedded Signal Visualization Workbenches: Use logic analyzers, digital storage oscilloscopes (DSOs), or Raspberry Pi serial plotters during laboratory hours so students can instantly witness real-time sampling impacts, quantization errors, and signal filtering changes.

15. Hardware Interfacing and Calibration Fault-Finding: Instruct students to configure, wire, and calibrate discrete proximity devices (Ultrasonic, IR, Hall Effect) against varying target distances, requiring them to document real-world sensor limitations like dead zones and cross-talk.

16. Structured Open-Ended Hardware Code-Sprints: Structure Part-B programming exercises (like FFT and digital convolution) by giving students raw input data frameworks on single-board computers, allowing them to independently construct signal-processing algorithms.

17. Interactive Peer Circuit Safety Inspections: Coordinate student-led peer review check blocks where teams examine each other's physical fluid power layouts (checking manifold connections, pressure relief valve settings, and sequence valve paths) before activating high-pressure fluid loops.

Assessment Structure:
The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.
For both CIE and SEE, the student is required to conduct one experiment each from both Part A and Part B.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment				
Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to analyze the output. (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Industrial Robot Laboratory		Scheme	2025
Course Code	**1BRIL406**	Semester	3
Teaching Hours/Week (L:T:P)	0:0:2	CIE Marks	50
Total Hours of Pedagogy L:T:P:SLTW	0:0:28:2	SEE Marks	50
Credits	1	Total Marks	100
Examination type (SEE)	**Practical**	Exam Hours	2

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

18. Evaluate the kinematic performance parameters and coordinate transformations of industrial manipulators.
19. Formulate and solve direct and inverse kinematic equations, including Jacobian and singularity analyses, for standard robot configurations.
20. Synthesize and simulate smooth trajectory profiles for robotic manipulator paths.

21. Design and program robotic automation routines for complex industrial tasks and vision-integrated operations.

Note:

5. The laboratory syllabus consists of PART-A and PART-B. While PART-A has 6 conventional experiments, PART-B has 6 typical open-ended experiments. The maximum marks for the laboratory course are 100.
6. Both PART-A and PART-B are considered for CIE and SEE.
7. Students have answer 1(one) question from PART-A and 1(one) question from PART-B.
   c. The questions set for SEE shall be from among the experiments under PART-A. It is evaluated for **70 marks** out of the maximum 100 marks.
   d. The open-ended question set for SEE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for **30 marks.**
8. For Continuous Internal Evaluation (CIE) during the semester, classwork shall typically include open-ended questions from **Part-B**, along with other similar questions designed to enhance the students' skills.

PART – A
FIXED SET OF EXPERIMENTS

7. Determination of maximum and minimum position of links.
8. Verification of transformation (Position and orientation) with respect to gripper and world coordinate system.
9. Estimation of accuracy, repeatability and resolution.
10. Robot programming and simulation for pick and place.
11. Robot programming and simulation for Colour identification.
12. Robot programming and simulation for Shape identification.
13. Robot programming and simulation for machining (cutting, welding).
14. Robot programming and simulation for any industrial process (Packaging, Assembly).

PART – B
OPEN ENDED EXPERIMENTS

Open-ended experiments are a type of laboratory activity where the outcome is not predetermined and students are given the freedom to explore, design, and conduct the experiment based on the problem statements as per the concepts defined by the course coordinator. It encourages creativity, critical thinking, and inquiry-based learning.

7. Experiments on direct kinematics using virtual labs or pipe models of 3R, SCARA, RPY robots
8. Experiments on inverse kinematics using virtual labs or pipe models of 3R, SCARA, RPY robots
9. Experiments on Linear and rotary joint Jacobian
10. Experiments on Estimation of Jacobian for (a) 2R robot (b) 3R robot

11. Experiments on Robot Singularities for (a) 2R robot (b) 3R robot
12. Experiments on simulation of polynomial trajectory

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

<u>Reference books / Manuals:</u>

11. **"Introduction to Robotics: Mechanics and Control" by *John J. Craig* (Pearson Education).**

Reference Book:

12. **"Industrial Robotics: Technology, Programming, and Applications" by *Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, and Nicholas G. Odrey* (McGraw-Hill).**
13. **"Robotics, Vision and Control: Fundamental Algorithms in MATLAB" by *Peter Corke* (Springer).**
14. **Virtual Labs (VLab) India — Mechanism and Robotics Lab (An initiative of Ministry of Education, Govt. of India / hosted by IITs).**

Web links and Video Lectures (e-Resources):

- **https://www.autodesk.com/certification/learn/course/learn-fusion-360-in-90-minutes**
- **Introduction to Modelling and Design for Manufacturing**
- **https://www.autodesk.com/certification/learn/course/fusion360-intro-modeling-designprofessional**

NPTEL / SWAYAM Video Lectures:

- ***Robotics / Industrial Automation (IIT Delhi / IIT Guwahati):* Recommended video playlists explaining coordinate transformation verifications, industrial work envelope calculations, and performance metrics like precision and repeatability.**

- ***Robot Kinematics and Dynamics:* Essential lectures for working out mathematical exercises on joint Jacobians, velocity mapping, and singularity avoidance configurations.**

Industrial Simulation Software Suites:

- ***ABB RobotStudio / FANUC RoboGuide / KUKA.Sim:* Powerhouse industrial tools used to build virtual manufacturing cells, calibrate tool center points (TCP), and simulate machining, welding, or pick-and-place paths.**

- ***RoboAnalyzer / Peter Corke's Robotics Toolbox:* Free academic software platforms perfectly suited for visualizing D-H parameter link transformations, 3R/SCARA profiles, and polynomial trajectories.**

Online Repositories and Virtual Labs:

- ***MHRD Virtual Labs (Robotics and Spatial Kinematics):* Online interactive simulation benches where students can test forward/inverse kinematic iterations and view workspace profiles digitally.**

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Digital Workspace Boundary Mapping: Guide students to use hardware teach pendants or simulator environments to systematically jog an industrial arm to its structural limits, creating a spatial plot of its minimum and maximum link envelopes.

- Interactive Coordinate Frame Calibrations: Coordinate live lab demonstrations where students shift reference perspectives, measuring how the robot's Tool Center Point (TCP) values dynamically update relative to the User, Robot Base, and World coordinate systems.

- Statistical Repeatability Verification Sprints: Run tracking exercises where students program a manipulator to approach a specific point multiple times, recording physical dial-indicator or digital gauge deviations to calculate real-world accuracy and resolution limits.

- Offline-to-Online Industrial Code Deployments: Instruct students to build, debug, and run end-effector paths (such as automated pick-and-place, welding beads, or sorting routines based on color/shape vision feedback) inside safe 3D virtual simulator setups before executing the code on live physical robots.

- Physical Pipe-Model Kinematic Build Seminars: Incorporate hands-on physical building sessions during Part-B blocks where students construct adjustable scale pipe models of 3R or SCARA layouts to physically confirm coordinate shifts, Jacobian configurations, and singularity locked states.

Assessment Structure:
The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.
For both CIE and SEE, the student is required to conduct one experiment each from both Part A and Part B.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment				
Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to analyze the output. (1-2)

Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Programme Specific Biology			
Course Code	1BRI407	Scheme	2025
Type of Course	Basic Science Course	Semester	IV
Teaching Hours/Week (L:T:P)	2: 0: 0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	28: 0: 0: 32	SEE Marks	50
Credits	**2**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

- **CO1:** Explain the organization of living systems, cell structure, and biological diversity.
- **CO2:** Interpret the basic principles of genetics and biological information transfer.
- **CO3:** Describe the role of biomolecules, enzymes, and metabolism in sustaining life processes.
- **CO4:** Apply biological concepts to understand engineering solutions in healthcare, environment, and sustainable technologies.

Module-1

Introduction to Biology and Living Systems

Introduction to Biology: Biology as a science, relevance of biology to engineering, characteristics of living organisms, levels of biological organization, biological systems as natural engineering systems.

Cell as the Basic Unit of Life: Cell theory, prokaryotic and eukaryotic cells, plant and animal cells, structure and functions of cell organelles, cell membrane and transport of materials.

Applications: Bio-inspired engineering, biological principles in modern technology and healthcare.

Number of Hours: 06

Module-2

Cells and Biological Diversity

Cell Organization: Structure–function relationship in living systems, specialization of cells and tissues. Biological Diversity: Overview of classification of living organisms, microorganisms, plants and animals, importance of biodiversity and ecosystem balance.

Applications: Microorganisms in industry, agriculture, environmental management, and biotechnology.

Number of Hours: 05

Module-3

Genetics and Information Transfer

Fundamentals of Genetics: Genes, chromosomes, heredity, Mendel's laws of inheritance, dominant and recessive traits.

Cell Division: Mitosis and meiosis, significance of cell division.

Information Transfer in Living Systems: DNA and RNA, structure and functions, DNA replication, central dogma of molecular biology, transcription and translation.

Applications: Genetic engineering, recombinant DNA technology, biotechnology and healthcare applications.

Number of Hours: 06

Module-4

Biomolecules, Enzymes and Metabolism
Biomolecules: Carbohydrates, proteins, lipids and nucleic acids; structure and biological significance.
Enzymes: Classification, properties, mechanism of enzyme action, factors affecting enzyme activity, industrial and medical applications.
Metabolism: Energy in biological systems, ATP as energy currency, overview of cellular respiration and energy conversion.
Applications: Biosensors, industrial biotechnology, enzyme-based technologies.

Number of Hours: 06

Module-5

Biology for Engineering Applications
Biological Technologies: Biomaterials, biosensors, biomedical devices, tissue engineering and regenerative medicine.
Environmental Biotechnology: Biofertilizers, biopesticides, biofuels, bioremediation and waste management.
Emerging Technologies: Bioinformatics, synthetic biology, artificial intelligence in biology, precision agriculture, bio-inspired robotics and sustainable engineering solutions.

Number of Hours: 05

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text Book

- Dr. Annamma Odaneth, Biology for Engineers, AICTE Training and Learning (ATAL) Academy, All India Council for Technical Education (AICTE), New Delhi. Available through the AICTE e-book initiative.

Reference Books

1. Thyagarajan S., Selvamurugan N., Rajesh M.P., Nazeer R.A., Thilagaraj W., Bharathi S. and Jaganathan M.K., Biology for Engineers, Tata McGraw-Hill Education, New Delhi.
2. Arthur T. Johnson, Biology for Engineers, CRC Press, Taylor & Francis.
3. Tanushree Chakraborty and Nasim Akhtar, Biology for Engineers, PHI Learning Pvt. Ltd., New Delhi. Designed around the AICTE Biology curriculum.
4. G.K. Suraishkumar, Biology for Engineers, Oxford University Press, New Delhi.

Web links and Video Lectures (e-Resources):

- https://nptel.ac.in/courses/121106008
- https://freevideolectures.com/course/4877/nptel-biology-engineers-other-non-biologists
- https://ocw.mit.edu/courses/20-020-introduction-to-biological-engineering-design-spring-2009
- https://ocw.mit.edu/courses/20-010j-introduction-to-bioengineering-be-010j-spring-2006
- https://www.coursera.org/courses?query=biology
- https://onlinecourses.nptel.ac.in/noc19_ge31/preview
- https://www.classcentral.com/subject/biology
- https://www.futurelearn.com/courses/biology-basic-concepts

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- **Case-Based Learning:** Discuss real-world applications of biology in agricultural engineering, mechanical systems, precision farming, biomaterials, and environmental sustainability.
- **Biomimicry-Based Problem Solving:** Encourage students to analyze natural systems and develop engineering solutions inspired by biological processes and structures.
- **Multimedia and Simulation-Based Learning:** Use animations, videos, virtual laboratories, and simulation tools to demonstrate biological processes and engineering analogies.
- **Group Discussions and Concept Mapping:** Facilitate collaborative learning through discussions on bio-inspired technologies, biotechnology applications, and emerging trends in bioengineering.
- **Project-Based Learning:** Assign mini-projects related to biosensors, smart farming, bioenergy systems, agricultural automation, and sustainable engineering solutions.
- **Flipped Classroom Approach:** Students explore learning resources before class and participate in interactive problem-solving sessions during class.
- **Industry and Research Exposure:** Invite experts from biotechnology, agricultural engineering, healthcare, and environmental sectors to deliver lectures on contemporary biological innovations.

- **ICT-Enabled Learning:** Utilize MOOCs, NPTEL lectures, online case studies, and digital content for self-paced learning.

Assessment Structure:
The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks.**

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks.**

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
5.	Case Study Presentation on Bio-inspired Engineering Applications	10
6.	Literature Review / Assignment on Emerging Bioengineering Technologies	15

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)	Excellent understanding and interpretation	Good understanding	Moderate understanding	Limited understanding	No understanding
Performance Indicator-2 (CO/PO Mapping)	Innovative application demonstrated	Appropriate application	Basic application	Weak application	No application
Performance Indicator-3 (CO/PO Mapping)	Highly effective	Effective	Satisfactory	Poor	Unsatisfactory

Suggested Learning Activities may include (but are not limited to): - Course Project - Case Study Presentation - Programming Assignment - Tool/Software Exploration - Literature Review - Open Book Test (preferably at RBL4 and RBL5 levels) - GATE-based Aptitude Test - Assignment (at RBL3, RBL4, or RBL5 levels) - Any other relevant and innovative academic activity - Use of MOOCs and Online Platforms
Suggested Innovative Delivery Methods may include (but are not limited to): - Flipped Classroom - Problem-Based Learning (PBL) - Case-Based Teaching - Simulation and Virtual Labs - Partial Delivery of course by Industry expert/ industrial visits - ICT-Enabled Teaching - Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
13.	Assignment on Biological Systems and Engineering Analogies	4
14.	Case Study on Biomimicry and Nature-Inspired Engineering	4
15.	Seminar on Emerging Bioengineering robotic Technologies	4
16.	Mini Project on Bio-Innovations in robotics	4
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
10.	NPTEL/MOOC Course Modules on Biology for Engineers	4
11.	Study of Precision Agriculture and Biosensors	4
12.	Exploration of Bio-inspired Technologies and Innovations	4

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

ENVIRONMENTAL SCIENCE PROJECT			
Course Code	**1BEP408**	Scheme	**2025**
Type of Course	Societal Development Course (SDC)	Semester	IV
Teaching Hours/Week (L:T:P)	30 (0:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	30 (0:0:0:30)	SEE Marks	50
Credits	**1**	Total Marks	100
Examination type (SEE)	**Theory**	Exam Hours	03

Course Objectives:

The Environmental Science Project is a practical, applied-learning course that builds students' environmental awareness and responsibility. It focuses on real issues such as climate change, pollution, biodiversity, resource use, soil erosion, and thermal comfort, using field surveys, case studies, data collection, audits, and analysis to develop feasible and sustainable solutions. Students may work individually or in groups of up to four, including interdisciplinary topics, and assessment is based on the prescribed rubrics.

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. **CO1 (L2 – Understand):** Identify and analyse environmental problems through field interaction and technical assessment.
2. **CO2 (L3 – Apply):** Develop skills in project planning, field survey, data collection, implementation, documentation and reporting.
3. **CO3 (L4 – Analyze):** Formulate feasible environmental problem statements and solutions considering practical constraints and sustainability aspects.
4. **CO4 (L3 – Apply):** Apply principles of environmental responsibility, ethics and societal welfare in engineering practice through community-oriented interventions.
5. **CO5 (L4 – Analyze):** Exhibit multidisciplinary learning and problem-solving ability based on collected data, user feedback and baseline conditions.
6. **CO6 (L5 – Evaluate):** Demonstrate teamwork and communication skills while interacting with technical and non-technical stakeholders and reflect on project impact on society.

Restrictions and professional conduct:

Environmental Science Projects should be academic, socially responsible, technically focused, and politically neutral. Students and faculty must maintain professionalism, ethical conduct, and respect while working with communities and stakeholders, and avoid any political, ideological, commercial, or disruptive activities. Projects should also consider practical constraints such as cost, resources, safety, environmental impact, and stakeholder cooperation.

SET OF PROJECT ACTIVITIES (TW/SL = 30 HOURS)

Methods for project identification:
Students may identify the project topic using one or more of the following methods: interaction with local rural or urban stakeholders such as local leaders, corporation/municipality personnel, NGOs, panchayat representatives, etc.; review of issues highlighted in print and electronic media, and social networks; and, after selecting a broad topic, collect data, conduct a feasibility survey, estimate timelines and resources, approximate expenditure, and define the problem statement and objectives clearly.
List of Project Topics and Engineering Outcomes:
The following structured sequence of activities is to be carried out during the semester:

Sl. No.	Project title	Measurable engineering outcome	Mapped POs	SDGs
1	Rural and urban water conservation and management systems	Prepare a site-specific water-saving plan, estimate water demand–supply gap, and propose a feasible conservation intervention with quantified savings.	PO1, PO2, PO3, PO4, PO10, PO11	SDG 6, SDG 11, SDG 12
2	Waste management and recycling	Conduct waste audit, classify waste streams, and design a segregation/recycling workflow with measurable reduction in mixed waste.	PO2, PO3, PO4, PO6, PO8, PO10	SDG 11, SDG 12, SDG 13
3	Afforestation	Identify a degraded area, prepare plantation layout, and demonstrate survival-rate tracking and maintenance schedule for saplings.	PO2, PO3, PO4, PO6, PO7, PO11	SDG 11, SDG 13, SDG 15
4	Biogas generation and power generation	Estimate organic waste availability, size a small biogas system, and document expected gas output or energy yield.	PO1, PO2, PO3, PO4, PO5, PO10	SDG 7, SDG 11, SDG 12
5	DPR for solar power rural plant	Prepare a DPR with load assessment, panel sizing, cost estimate, and projected energy generation and payback.	PO1, PO2, PO3, PO4, PO5, PO10	SDG 7, SDG 9, SDG 11
6	DPR for electrification of village/tribal community	Map unserved/underserved households, propose electrification layout, and estimate coverage, losses, and implementation cost.	PO1, PO2, PO3, PO4, PO10, PO11	SDG 7, SDG 9, SDG 10
7	DPR for rural drainage system	Survey drainage bottlenecks, develop a drainage layout, and estimate runoff handling capacity and flood-risk reduction.	PO1, PO2, PO3, PO4, PO6, PO10	SDG 6, SDG 9, SDG 11
8	Sustainability and environmental health projects	Assess local environmental health issues and propose interventions with measurable improvement in hygiene, safety, or resource use.	PO2, PO3, PO4, PO6, PO7, PO8	SDG 3, SDG 6, SDG 11, SDG 12
9	Plastic free campaigns	Measure plastic usage before and after awareness intervention and report percentage reduction or behavioural change.	PO2, PO3, PO6, PO7, PO8, PO10	SDG 11, SDG 12, SDG 13
10	Health and nutrition awareness	Conduct baseline and post-program awareness survey and daocument improvement in awareness score or adoption of healthier practices.	PO2, PO6, PO7, PO8, PO9, PO10	SDG 2, SDG 3, SDG 11

11	Societal projects involving health wellness	Identify a community health need and develop an awareness/service module with measurable participation and feedback outcomes.	PO2, PO3, PO6, PO8, PO9, PO10	SDG 3, SDG 11, SDG 17
12	Air quality monitoring system	Collect air-quality data, compare with reference limits, and present trends along with possible mitigation suggestions.	PO2, PO3, PO4, PO5, PO6, PO10	SDG 3, SDG 11, SDG 13
13	Plastic waste reduction campaign	Track collection, segregation, and replacement actions, and quantify reduction in plastic waste generation or littering.	PO2, PO3, PO6, PO7, PO8, PO10	SDG 11, SDG 12, SDG 13
14	Urban greening projects	Prepare greening plan, identify planting locations, and assess environmental benefits such as shade, aesthetics, or heat mitigation.	PO2, PO3, PO4, PO6, PO7, PO11	SDG 11, SDG 13, SDG 15
15	Smart agriculture solution	Design a low-cost monitoring or irrigation support solution and estimate improvement in water use efficiency or crop support.	PO1, PO2, PO3, PO4, PO5, PO10	SDG 2, SDG 6, SDG 9
16	Smart irrigation system	Estimate crop water requirement, propose control logic, and quantify water savings compared with conventional irrigation.	PO1, PO2, PO3, PO4, PO5, PO10	SDG 2, SDG 6, SDG 12
17	Food security initiatives / cold storage system	Estimate storage need, design a simple cold-chain concept, and document reduction in spoilage or wastage.	PO1, PO2, PO3, PO4, PO5, PO10	SDG 2, SDG 9, SDG 12

Suggested Learning Resources

Particulars	Titles and Publishers
Textbooks	1. Phadke, N. D., *Community Engagement and Social Innovation*, Oxford University Press, New Delhi. 2. Garg, N. R., *Project-Based Learning in Engineering Education*, Pearson India Education Services, Noida. 3. Gupta, A. and P. Singh, *Service Learning and Community Projects*, McGraw-Hill Education (India), New Delhi. 4. Wilson, G., *Practical Guide to Community Development Projects*, Routledge, London.
Reference books	1. NPTEL courses on Project-Based Learning and Social Innovation. 2. SWAYAM courses on community engagement and sustainability. 3. UN Sustainable Development Goals portal. 4. MyGov India and local civic body portals for community initiatives. 5. YouTube resources on design thinking, social innovation, and community service learning. 6. NGO and government field-action case studies related to sanitation, water, health, education, and environment.
Web links and Video Lectures (e-Resources)	1. NPTEL courses on Engineering Geology. 2. NPTEL courses on Soil Mechanics and Foundation Engineering. 3. Virtual Labs – Geotechnical Engineering Virtual Lab. 4. Geological Survey of India. 5. YouTube channels on civil engineering experiments. 6. American Society of Civil Engineers (ASCE) – Geotechnical resources and standards.

Teaching Learning Process:

The suggested TLP for Community / Societal Project is as follows;

Week / Phase	Teaching–Learning Activity	Faculty Role	Student Activity	Output / Evidence
1	Course introduction, objectives, ethics, conduct, and assessment briefing	Explain course scope, rules, rubrics, and expected deliverables	Understand course requirements and form teams	Team list, course plan
2	Community problem identification and topic selection	Guide topic framing and feasibility	Identify local issues through discussion and observation	Shortlisted project topic
3	Stakeholder interaction and preliminary survey	Demonstrate survey methods and stakeholder engagement	Collect initial data from community/users	Survey notes, interview record
4	Problem statement and objective formulation	Review and refine problem statement	Prepare problem statement, scope, and objectives	Approved problem statement
5	Literature/case study review and baseline analysis	Suggest relevant references and examples	Study existing solutions and compare approaches	Baseline analysis summary
6	Project planning and role assignment	Help teams organize tasks, timeline, and responsibilities	Plan activities, divide roles, and prepare schedule	Work plan / Gantt chart
7	Feasibility analysis and solution brainstorming	Check technical feasibility and practicality	Generate possible engineering solutions	Solution alternatives sheet
8	Selection of final solution and design approach	Review final concept and design logic	Finalize concept, methods, and expected outcome	Concept note / design outline
9	Data processing / calculations / sizing / mapping	Support computations and technical review	Analyze data, perform calculations, prepare maps/charts	Technical analysis sheet
10	Prototype / model / audit / DPR / app development	Monitor progress and correct technical issues	Develop the selected output	Working model / draft DPR / map / app
11	Testing, refinement, and implementation planning	Evaluate technical correctness and improvements	Test prototype or validate proposal with users	Test results / revised output
12	Field implementation / demonstration / awareness activity	Facilitate community interaction and documentation	Conduct implementation or demonstration	Photos, attendance, implementation record
13	Documentation of outcomes, feedback, and impact	Review report structure and completeness	Compile findings, stakeholder feedback, and observations	Draft report

14	Presentation preparation and viva practice	Conduct mock presentation and feedback	Prepare slides/poster and rehearse	Presentation deck
15	Final presentation, submission, and reflection	Evaluate performance using rubrics	Present project, submit report, reflect on learning	Final report, presentation, viva

Assessment structure:

A. Continuous Internal Evaluation (CIE) – 50 marks

- Students, in batches of 3–4, shall undertake at least one project (or a combination of two related activities) aiming, as far as possible, at a logical implemented or implementable outcome.
- CIE will be conducted by a departmental committee (HoD/nominee, guide and one senior faculty) using the following rubrics totalling 50 marks:

CIE pass requirement:

A student shall secure a minimum of 20 marks out of 50 in CIE to become eligible to appear for SEE.

- Students who fail to earn the required CIE marks may be given additional opportunities before closure of the semester; no re-doing of CIE is permitted after the end of the semester.

B. Semester End Examination (SEE) – 100 marks (scaled to 50)

- Examination duration: 2 hours.
- Maximum examination marks: 100 (entered as 100 in the VTU portal; the ITI-SMU module automatically scales 100 → 50 for result processing).
- The SEE shall be conducted batch-wise by a committee of three faculty: project guide, one faculty from the same department and one from a different department.

SEE pass requirement and overall passing rule:

- For a pass in SEE, a student shall secure minimum 35 marks out of 100.
- For declaration of a pass grade, the sum of CIE marks (out of 50) and scaled SEE marks (out of 50) shall be ≥ 40; otherwise, the student is awarded grade F (Fail).

CIE Rubric — Continuous Internal Evaluation (Total 50 marks):

Criterion	**Weight (marks)**	**Excellent (Full marks)**	**Good**	**Fair**	**Needs Improvement**
Problem identification & relevance to society/environment	8	Problem clearly identified with strong evidence of relevance and well-defined scope.	Relevant problem with clear scope and adequate evidence.	Problem defined but justification is weak.	Problem unclear or not relevant.
Formation of problem statement; engineering approach, innovation & feasibility	10	Precise statement; sound, innovative, feasible approach.	Adequate statement; feasible with minor gaps.	Partial statement; marginal feasibility.	Missing or infeasible.
Interaction with stakeholders; data collection, analysis & interpretation	8	Thorough engagement; comprehensive data and well-interpreted analysis.	Good engagement; adequate data and analysis.	Limited engagement; incomplete data and superficial analysis.	Little or no stakeholder contact; no data/analysis.

Project documentation; clarity, organization & problem-solving demonstrated	10	Complete, well-organized, analytical, and strong problem-solving.	Complete and clear with some analytical content.	Basic with omissions; problem-solving limited.	Missing/poorly organized; no clear problem-solving.
Communication & presentation skills	6	Confident, structured, and answers queries fully; visuals effective.	Clear and satisfactory; responds to most queries.	Acceptable but lacks clarity or confidence; weak responses.	Poor or absent; unable to respond.
Contribution & benefit to society (impact, sustainability)	8	Clear, demonstrable societal benefit and realistic sustainability path.	Benefit plausible; sustainability considered with minor gaps.	Limited or unclear benefit; sustainability weak.	No evident benefit or sustainability.

Notes for CIE rubric:

- Minimum CIE pass requirement: 20/50 to be eligible for SEE. [Use departmental committee (HoD/guide + senior faculty) to apply the rubric and record marks.]

SEE Rubric — Semester End Examination (Enter marks out of 100; scaled to 50 later):

Criterion	Weight (marks)	Excellent (Full marks)	Good	Fair	Needs Improvement
Problem identification & relevance to society/environment	16	Clearly articulated with strong evidence and context.	Clear with reasonable evidence.	Problem stated but evidence/context weak.	Poorly defined or irrelevant.
Formation of problem statement; engineering approach, innovation & feasibility	20	Precise; demonstrates engineering depth, novelty and feasibility.	Technically sound and feasible with minor limitations.	Basic; limited technical depth or feasibility concerns.	No viable engineering approach or infeasible plan.
Interaction with stakeholders; data collection, analysis & interpretation	16	Excellent engagement; rigorous data collection and insightful analysis.	Good engagement and acceptable analysis.	Superficial data collection and limited analysis.	Inadequate or no data; poor analysis.
Project documentation; clarity, technical rigor & problem-solving demonstrated	20	Comprehensive, technically rigorous, and systematic.	Complete and technically correct with minor gaps.	Lacks technical depth or has notable omissions.	Missing key elements or technically incorrect.

Communication, presentation & viva-voce responses	12	Presents expertly, defends work persuasively and answers all queries correctly.	Good presentation and satisfactory answers to most queries.	Adequate but fails to answer some technical questions.	Poor presentation and unable to defend work.
Contribution & benefit to society; impact assessment & sustainability	16	Clear, evidence-based impact assessment with scaling recommendations.	Reasonable impact discussion and sustainability considerations.	Limited evaluation of impact or sustainability.	No coherent assessment of impact or sustainability.

SEE pass rule:

- Student must secure at least 35/100 in SEE itself to be eligible for pass consideration.
- Final passing is based on CIE (out of 50) + SEE (scaled to 50) >= 40. Otherwise, grade F (Fail) is awarded.

Suggested implementation notes (for BoS / exam committees):

- Use numerical scores from the rubric and keep brief evaluator comments for each criterion.
- For team projects: record individual contribution within the documentation and adjust individual marks using a peer-evaluation sheet or guide's assessment.
- Maintain evidence (field notes, photos, questionnaires, DPRs, reports) as annexures for SEE moderation.
- Use standardized score sheet (spreadsheet) mapping rubric items to columns for easy aggregation and archival.

- Awareness Campaign on Single-Use Plastic and E-Waste Management

Suggested Learning Resources:

Text Books:

1. Benny Joseph, *Environmental Studies*, Tata McGraw-Hill, 2nd Edition.
2. R. Rajagopalan, *Environmental Studies: From Crisis to Cure*, Oxford University Press, 2005.
3. Erach Bharucha, *Textbook of Environmental Studies*, University Press, latest edition as available in library.
4. M. P. Poonia and S. C. Sharma, *Environmental Studies*, Vikas Publishing House, latest edition as available

Reference Books:

1. R. Sivakumar, Principles of Environmental Science and Engineering, Cengage Learning, 2nd Edition.
2. G. Tyler Miller Jr., Environmental Science: Working with the Earth, Thomson Brooks/Cole, 11th Edition.
3. Pratibha Singh, Anoop Singh, and Piyush Malaviya, Text Book of Environmental and Ecology, Acme Learnin 1st Edition.
4. S. M. Prakash, Environmental Studies, Elite Publishing House, Mangalore, 3rd Edition, 2018.

Web links and Video Lectures (e-Resources):

1. VTU e-Learning Centre: http://elearning.vtu.ac.in
2. VTU e-Resources / e-Content: http://elearning.vtu.ac.in/e-Res.php
3. VTU e-Shikshana Lecture Videos: http://elearning.vtu.ac.in/esk3.php
4. VTU Consortium Digital Resources: https://access.vtuconsortium.com/msec
5. VTU e-Learning Centre: http://elearning.vtu.ac.in
6. VTU e-Resources / e-Content: http://elearning.vtu.ac.in/e-Res.php
7. VTU e-Shikshana Lecture Videos: http://elearning.vtu.ac.in/esk3.php
8. VTU Consortium Digital Resources: https://access.vtuconsortium.com/msec

Assessment Structure:

Continuous Internal Evaluation (CIE) shall be conducted by the Departmental Project Review Committee consisting of a Senior Professor, the Project Guide, and one additional faculty member nominated by the Head of the Department. Semester End Evaluation (SEE) shall be conducted by university-appointed examiners. The evaluation shall be based on rubrics designed to assess the attainment of NBA-defined graduate attributes, including problem analysis, investigation, design of solutions, communication, teamwork, and professionalism.

The weightage of marks for CIE and SEE is 50% each.

Pass Criteria: A candidate shall secure a minimum of 40% of the total marks prescribed for Project Work, subject to the required minimum in Continuous Internal Evaluation and Semester End Evaluation as per VTU regulations.

Sample Rubrics for Campus water-quality and development of a water-conservation plan.

Criterion	Weight (%)	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs improvement
Problem definition and campus context	10	Clearly defines campus water issue, boundaries, water sources, and purpose.	Defines issue and context with minor gaps.	Basic problem stated, but scope is incomplete.	Vague or incorrect problem definition.
Water-quality data collection	15	Uses appropriate sampling points, methods, and frequency; data are well documented.	Methods are mostly appropriate with minor omissions.	Limited methods or incomplete documentation.	Weak or unclear data collection.
Water-quality parameters and	20	Correctly analyzes key physical,	Analyzes most parameters	Some parameters	Minimal or incorrect

Criterion	Weight (%)	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs improvement
analysis		chemical, and microbiological parameters and interprets results.	correctly with minor interpretation gaps.	analyzed, but interpretation is weak.	analysis.
Evidence and standards comparison	15	Compares results against relevant standards/guidelines and draws valid conclusions.	Compares most results with reasonable conclusions.	Comparison is partial or uneven.	No meaningful comparison with standards.
Diagnosis of issues and causes	10	Identifies likely causes of poor quality or water loss using evidence.	Identifies main causes with some support.	Causes are mentioned, but weakly supported.	Causes are speculative or absent.
Conservation plan objectives and measures	15	Plan includes clear goals, realistic measures, prioritization, and campus suitability.	Plan is relevant and mostly realistic.	Plan has some useful measures but limited prioritization.	Plan is generic or impractical.
Feasibility and implementation	10	Addresses resources, responsibilities, timeline, and implementation steps clearly.	Covers most implementation aspects.	Implementation is partial or underdeveloped.	Little or no implementation planning.
Cost, savings, and sustainability	5	Provides reasonable cost-benefit thinking and expected savings.	Includes some cost or savings discussion.	Limited financial/savings analysis.	No cost or savings consideration.
Presentation and documentation	0–10	Clear structure, tables/figures, references, and professional report quality.	Well organized with minor issues.	Acceptable but uneven formatting or writing.	Poorly organized and difficult to follow.

Design of Robotic components

Course Code	**1BRI409**	Scheme	2025
Type of Course	**PCC**	Semester	3
Teaching Hours/Week (L:T:P)	3:0 :0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42: 00: 00: 48	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

22. Analyze static failure and select materials using appropriate engineering design theories and standards.

23. Evaluate robotic components under fatigue and impact loading considering stress concentration effects.
24. Design power transmission shafts, keys, and threaded fasteners based on strength, rigidity, and standard codes.
25. Synthesize and select mechanical drives, belts, gears, and bearings for robotic system applications.

Module-1

Introduction: Design Process: Definition of design, phases of design, and review of engineering materials and their properties and manufacturing processes; use of codes and standards, selection of preferred sizes.

Design for static strength: Factor of safety and service factor. Failure mode: definition and types. Failure of brittle and ductile materials; even and uneven materials; Theories of failure: maximum normal stress theory, maximum shear stress theory, distortion energy theory, strain energy theory.

Number of Hours: 8

Module-2

Stress concentration, stress concentration factor and methods of reducing stress concentration.

Impact Strength: Introduction, Impact stresses due to axial, bending and torsion loads.

Fatigue loading: Introduction to fatigue failure, Mechanism of fatigue failure, types of fatigue loading, S-N Diagram, Low cycle fatigue, High cycle fatigue, Endurance limit.

Module-3

Design of shafts: Torsion of shafts, solid and hollow shaft design with steady loading based on strength and rigidity, ASME and BIS codes for power transmission shafting.

Design of keys: Types of keys and their applications, design considerations in parallel and tapered sunk keys, Design of square and rectangular sunk keys.

Threaded Fasteners: Types of screw fastening, Forms of threads, Stresses in threaded Fasteners, Initial Stresses due to Screwing up Forces, Stresses due to External Forces, Stress due to Combined Forces.

Number of Hours: 8

Module-4

Belts: Materials of construction of flat and V belts, power rating of belts, concept of slip and creep, initial tension, effect of centrifugal tension, maximum power condition. Selection of flat and V belts- length & cross section from manufacturers' catalogues. Construction and application of timing belts.

Gear drives: Classification of gears, materials for gears, standard systems of gear tooth, lubrication of gears, and gear tooth failure modes. Spur Gears: Definitions, stresses in gear tooth: Lewis equation and form factor, design for strength, dynamic load and wear.

Number of Hours: 8

Module-5

Lubrication and Bearings: Lubricants and their properties, bearing materials and properties; mechanisms of lubrication, hydrodynamic lubrication, pressure development in oil film, bearing modulus, coefficient of friction, minimum oil film thickness, heat generated, and heat dissipated. Numerical examples on hydrodynamic journal and thrust bearing design.

Antifriction bearings: Types of rolling contact bearings and their applications, static and dynamic load carrying capacities, equivalent bearing load, load life relationship; selection of bearings subjected to cyclic loads and speeds; probability of survival.

Number of Hours: 8

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

8. **Shigley's Mechanical Engineering Design, Richard G. Budynas, and J. Keith Nisbett, McGraw-Hill Education**
9. Design of Machine Elements, V B Bhandari, Tata McGraw Hill,
10. Design of Machine Elements-II, Dr.M H Annaiah, New Age International (P) Ltd.,

<u>Reference books / Manuals:</u>

15. Machine Design- an integrated approach, Robert L. Norton, Pearson Education, 2 nd edition.
16. Design and Machine Elements, Spotts M.F., ShoupT.E, Pearson Education, 8 th edition, 2006
17. Machine design Hall, Holowenko, Laughlin (Schaum's Outline Series), adapted by S.K.Somani, Tata McGraw Hill Publishing Company Ltd, Special Indian Edition, 2008

Design Data Hand Books:

[1] Design Data Hand Book, K.Lingaiah, McGraw Hill, 2nd edition, 2003.

[2] Design Data Hand Book, K.Mahadevan and Balaveera Reddy, CBS publication.

[3] Design Data Hand Book, H.G.Patil, I.K.International Publisher, 2010

[4] PSG Design Data Hand Book, PSG College of technology, Coimbatore

Web links and Video Lectures (e-Resources):

NPTEL / SWAYAM Video Lectures:

1. Design of Machine Elements (IIT Kharagpur/IIT Madras): Exceptional foundational video series covering Theories of Failure (Module 1), Fatigue Loading (Module 2), and Shafts, Keys, and Fasteners (Module 3).
2. Design of Transmission Systems: Ideal for deep-diving into Belts, Spur Gears (Module 4), and Hydrodynamic/Antifriction Bearings (Module 5).

Digital Learning Repositories & Tools:

1. V-Lab (Virtual Labs Engineering): Machine design and kinematics virtual simulation labs to visualize stress concentration and failure modes.
2. AGMA (American Gear Manufacturers Association) & ASME Digital Collection: Web links to reference standards for power transmission shafting and gear tolerances.

Manufacturer Catalogues for Practical Selection (Module 4 & 5):

1. SKF / FAG Bearing Interactive Catalogues: Online tools for calculating rolling contact bearing life equations and probability of survival.
2. Fenner / Gates Belt Drive Selection Manuals: Digital charts for open/V-belt length and cross-section selections based on power ratings.

Teaching-Learning Process (Innovative Delivery Methods):

1. Case-Based Learning on Component Failure: Discuss real-world case studies of structural and fatigue failures in robotic joints to help students analyze and apply static/dynamic failure theories.

2. CAD/CAE-Integrated Design Verification: Incorporate finite element analysis (FEA) software tools to let students model components like shafts and visually observe stress concentration zones alongside analytical calculations.

3. Hands-On Disassembly and Inspection: Organize classroom "show-and-tell" sessions using physical hardware (e.g., dismantled gearboxes, old robotic limbs) to inspect keys, fasteners, timing belts, and bearings firsthand.

4. Catalogue-Driven Engineering Problems: Utilize actual industrial manufacturer e-catalogues for assignments, training students to select appropriate standard belts and bearings based on calculated design constraints.

5. Blended Learning via Digital Repositories: Leverage NPTEL, SWAYAM, and virtual simulation laboratory links to reinforce complex mathematical design equations for hydrodynamic bearings and gear tooth profiles.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks.**

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
7.		
8.		

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
17.		
18.		
19.		
20.	(Add rows if required)	

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
13.		
14.		
15.		
16.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).