**COURSE HANDBOOK**

**ON**

**APPLIED LINEAR ALGEBRA (MTH 3003)**

***(4th Semester)***



**DEPARTMENT OF MATHEMATICS**

**Faculty of Engineering and Technology,**

**Institute of Technical Education and Research**

**SIKSHA ‘O’ ANUSANDHAN (DEEMED TO BE) UNIVERSITY**

**Bhubaneswar, Odisha, India**

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**PREFACE**

This course handbook contains all the necessary details of the concerned subject, i.e., Applied Linear Algebra (MTH 3003). It is designed in order keep up with the Outcome Based Education **(OBE)**. The handbook provides necessary details about the Grading Pattern, Grading System, Course Assessment, Assessment Rubrics, the Outcomes (POs, PEOs, PSOs), Bloom’s Taxonomy, Graduation CGPA requirements, Minimum Requirements for Passing Grade and Appearing the (Deemed to be University) Examination.

1. **Course Details**

Name of the Course : Applied Linear Algebra

Course Code : MTH 3003

Course Credits : 4

Grading Pattern : 6

Branch and Semester : Computer Science and Engineering, 4th Semester

Name of the Instructor: Prof. (Dr.) Sampada Kumar Parida

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| **SUBJECT CODE** | **SUBJECT NAME** | **CREDIT** | **GRADING PATTERN** |
| --- | --- | --- | --- |
| MTH 3003 | Applied Linear Algebra | 4 | 6 |
| Concepts : System of Linear Equations, Row & Column pictures, Elimination Methods, LU, LDU factorization, Vector Space, Linear dependency, Basis Dimensions, Four Fundamental Spaces, Orthogonality, Determinants, Eigen values and Eigen vectors, Positive definiteness, SVD, Pseudoinverse, iterative methods, Matrix norm, Condition Number. | | Text Book:   |  | Linear Algebra and its application by Gilbert Strang (4th edition), | | --- | --- | | |
| Course Format:  4 Classes/Week, 1 hr/Class: 4 1hr Theory sessions/Week = 4 Credits | |

1. **Course Outcomes (COs) and Mapping Course Outcomes with Program Outcomes (POs)**

| **Course Outcomes** | | **Program Outcomes** |
| --- | --- | --- |
| CO1 | Apply Gauss elimination principle to solve system of linear equations and elementary matrices to get LU & LDU factorization of a matrix. | PO1, PO2 |
| CO2 | Explain vector space, subspace, null space and column space, linear independence, basis and dimension of vector space and four fundamental subspaces, linear transformations and their applications . | PO1, PO2 |
| CO3 | Explainbasis and dimension of vector space and four fundamental subspaces, linear transformations and their applications | PO1, PO2 |
| CO4 | Explain orthogonality and its applications to find best fit solutions by least squares. Apply properties of determinants to solve the system of equations | PO1, PO2 |
| CO5 | Explain eigenvalues and eigenvectors and their application to solve system of differential equations and apply it to complex matrices, diagonalization of matrix and similarity transformations | PO1, PO2, PO12 |
| CO6 | Apply Gauss elimination principle to solve system of linear equations and elementary matrices to get LU & LDU factorization of a matrix. | PO1, PO2, PO12 |

\*Refer Appendix for list of Pos

1. **Course Articulation Matrix**

| **COs** | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PO7** | **PO8** | **PO9** | **PO10** | **PO11** | **PO12** | **PSO1** | **PSO2** | **PSO3** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| CO1 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| CO2 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| CO3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| CO4 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| CO5 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 3 | 0 |
| CO6 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 0 |

\*0: No correlation, 1: Slight (Low), 2: Moderate, 3: Substantial (High)

\*Refer Appendix for list of POs

1. **Justifications of Mapping**

Justification about the correlation between COs Vs POs & PSOs mentioned in the Articulation Matrix. Please describe the justifications.

1. **Credits and Grading Pattern:** The Subject, Applied Linear Algebra (MTH 3003) has 4 Credits, and belongs to Grading Pattern 6. The  **Grading Pattern** will be for those Subjects which are of 4 credits and which are of only theory components. The breakdown required for the calculation of the Numeric Score (out of 100) for Grading Pattern 6 is given below.

| **ATTENDANCE** | | 5 |
| --- | --- | --- |
| **MAJOR LAB / SESSION ASSIGNMENTS / QUIZZES** | | 10 |
| **MINOR ASSIGNMENTS** | | 10 |
| **MID TERM** | | 15 |
| **TOTAL INTERNAL** | | 40 |
| **IN LAB EXAM** | 0 | |
| **THEORY EXAM** | 60 | |
| **TOTAL EXTERNAL** | 60 | |

1. **Tentative Lesson Plan**

| **Lecture/Lab #** | **Tasks** | **Mapping with COs** |
| --- | --- | --- |
| Lecture # 1 | Introduction to the Course and syllabus | **All COs, POs, PSOs** |
| Lecture # 2 | The Geometry of Linear Equations | **CO1** |
| Lecture # 3 | The Geometry of Linear Equations | **CO1** |
| Lecture # 4 | Gaussian Elimination | **CO1** |
| Lecture # 5 | Gaussian Elimination | **CO1** |
| Lecture # 6 | Matrix Notation and Matrix Multiplication | **CO1** |
| Lecture # 7 | Triangular Factors and Row Exchanges | **CO1** |
| Lecture # 8 | Triangular Factors and Row Exchanges | **CO2** |
| Lecture # 9 | Inverses and Transposes | **CO2** |
| Lecture # 10 | Inverses and Transposes | **CO2** |
| Lecture # 11 | Vector Spaces and Subspaces | **CO2** |
| Lecture # 12 | Vector Spaces and Subspaces | **CO3** |
| Lecture # 13 | Solving *Ax* = 0 and *Ax* = *b* | **CO3** |
| Lecture # 14 | Solving *Ax* = 0 and *Ax* = *b* | **CO3** |
| Lecture # 15 | Solving *Ax* = 0 and *Ax* = *b* | **CO3** |
| Lecture # 16 | Linear Independence | **CO3** |
| Lecture # 17 | Basis, and Dimension | **CO3** |
| Lecture # 18 | Basis, and Dimension | **CO3** |
| Lecture # 19 | The Four Fundamental Subspaces | **CO3** |
| Lecture # 20 | The Four Fundamental Subspaces | **CO4** |
| Lecture # 21 | Orthogonal Vectors and Subspaces | **CO4** |
| Lecture # 22 | Cosines and Projections onto Lines | **CO4** |
| Lecture # 23 | Cosines and Projections onto Lines | **CO4** |
| Lecture # 24 | Projections and Least Squares | **CO4** |
| Lecture # 25 | Projections and Least Squares | **CO4** |
| Lecture # 26 | Properties and Formulas of the Determinant | **CO4** |
| Lecture # 27 | Applications of the Determinant | **CO4** |
| Lecture # 28 | Applications of the Determinant | **CO4** |
| Lecture # 29 | Eigenvalues and Eigenvectors | **CO4** |
| Lecture # 30 | Eigenvalues and Eigenvectors | **CO5** |
| Lecture # 31 | Eigenvalues and Eigenvectors | **CO5** |
| Lecture # 32 | Eigenvalues and Eigenvectors | **CO5** |
| Lecture # 33 | Eigenvalues and Eigenvectors |  |
| Lecture # 34 | Diagonalization of a Matrix | **CO5** |
| Lecture # 35 | Diagonalization of a Matrix | **CO5** |
| Lecture # 36 | Application of Diagonalization of a Matrix | **CO5** |
| Lecture # 37 | Complex Matrices | **CO5** |
| Lecture # 38 | Complex Matrices | **CO5** |
| Lecture # 39 | Complex Matrices | **CO6** |
| Lecture # 40 | Complex Matrices | **CO6** |
| Lecture # 41 | Complex Matrices | **CO6** |
| Lecture # 42 | Tests for Positive Definiteness | **CO6** |
| Lecture # 43 | Tests for Positive Definiteness | **CO6** |
| Lecture # 44 | Singular Value Decomposition | **CO6** |
| Lecture # 45 | Singular Value Decomposition | **CO6** |
| Lecture # 46 | Singular Value Decomposition | **CO6** |
| Lecture # 47 | Matrix Norm and Condition Number | **CO6** |
| Lecture # 48 | Iterative Methods for *Ax* = *b* | **CO6** |

1. **Assessment Rubric for the Course**

**Method:** Assignments, Quiz, Mid-Semester and End-Semester Exam

**Outcomes Assessed:**

***PO1 – Engineering knowledge:*** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

***PO2 – Problem analysis:*** Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

***PO12 – Life-long learning:***Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

**PSO1-** Graduates of Computer Science Engineering will achieve excellence in product design, thermal engineering and manufacturing system, innovation and entrepreneurship by acquiring knowledge in mathematics, science and designing principles.

**PSO2-** Graduates will be able to design an experiment as well as to analyse, interpret and provide solutions to the real-life Computer Science engineering problems.

**PSO3-** Graduates will be able to understand the impact of engineering solutions in a global, economic, environmental, and societal context and to use the though in the multidisciplinary problems.

| **Mid-Semester and End-Semester Examination Rubrics** | | | |
| --- | --- | --- | --- |
| **Performance** | **High (2 Marks)** | **Medium (1-1.5 Marks)** | **Low (0.5 Marks)** |
| Theoretical representation of concepts | Properly able to define, represent, and interpret the physical significance. | Minor errors in definition, representation and interpretation of physical significance. | Incomplete or poor definition, representation and interpretation of physical significance. |
| Pictorial representation of ideas | Neat, clean and proper sketches, graphs with proper labelling and interpretation. | Sketches and Graphs are drawn but interpretation of significance is not done or labelling is missing. | The pictures are unclear/not labelled and the interpretation is inappropriate. |
| Solving mathematical and/or design problems and interpreting the results | Selection of appropriate concepts to formulate. Ability to solve problems, represent them pictorially and interpret the results. | Able to select correct concepts, formulate, represent and solve, but error in interpreting | Erroneous selection of concepts, able to represent and formulate only, but error in solving. |

| **Rubrics for Quiz** | | | |
| --- | --- | --- | --- |
| **Performance** | **High (9-10 Marks)** | **Medium (7-8 Marks)** | **Low (4-6 Marks)** |
| Short/Long Answer Type Questions | The student has answered all the questions correctly and depicted them in a neat and clean manner, with appropriate explanation. | The student has answered most of the questions correctly and depicted them in a satisfactory manner. | The student has answered some of the questions correctly, though, with improper /erroneous/incomplete justification of the same. |
| MCQ Type Questions | The student has attended all the quizzes and attempted all the questions correctly. | The student has attended most of the quizzes and attempted most of the questions correctly. | The student has attended some of the quizzes and answers few of the questions correctly. |

| **Rubrics for Assignments** | | | |
| --- | --- | --- | --- |
| **Performance** | **High (9-10 Marks)** | **Medium (7-8 Marks)** | **Low (4-6 Marks)** |
| Completion and Submission of Assignments | Completed and submitted all assignments within deadline. The answers are depicted correctly, completely and in a neat and clean manner. The answers maybe unique/innovative. | Completed and submitted above 80% of the assignments. Submission is by the due date. The answers were fairly represented. | Completed 60% of the assignments. The submissions were made after repeated reminders, and in the extended deadline period. The answers were fairly represented. |

***Note – For specific assessments, specific rubrics may be followed.***

1. **Course Related Surveys**
2. **Pre-requisite Survey:** The objective of this survey is to know the basic understanding and different skills relevant to the subject, i.e., Applied Linear Algebra (MTH 3003). Please respond to the questions by clicking any one of the options against each of the following questions.

| 1. Ability to apply theoretical knowledge in day-to-day life (PO1,PO2). | | |
| --- | --- | --- |
| (a) Low Understanding | (b) Medium | (c) Adequate/High |
| 2. Multidisciplinary skills and ability to work in a team (PO11). | | |
| (a) Low Understanding | (b) Medium | (c) Adequate/High |
| 3. Communication and project management skills. | | |
| (a) Low Understanding | (b) Medium | (c) Adequate/High |
| 4. Ability to solve numerical and to plot graphs (PO1, PO2). | | |
| (a) Low Understanding | (b) Medium | (c) Adequate/High |
| 5. Simulation skills (PO5). | | |
| (a) Low Understanding | (b) Medium | (c) Adequate/High |
| 6. Basic knowledge about Matrices (PO1). | | |
| (a) Low Understanding | (b) Medium | (c) Adequate/High |
| 7. Understanding of Linear system of equations (PO1). | | |
| (a) Low Understanding | (b) Medium | (c) Adequate/High |
| 8. Knowledge of processes involving Linear system of equations (PO1). | | |
| (a) Low Understanding | (b) Medium | (c) Adequate/High |
| 9. Understanding of basics of Calculus (PO1). | | |
| (a) Low Understanding | (b) Medium | (c) Adequate/High |
| 10. Knowledge about the Matrix operations (PO1). | | |
| (a) Low Understanding | (b) Medium | (c) Adequate/High |

**Interim Course Progress Survey:** The objective of this survey is to know the students’ progress in basic understanding and attaining different outcomes relevant to the subject, i.e., Applied Linear Algebra (MTH 3003). Please respond to the questions by clicking any one of the options against each of the following questions. The outputs will be shared with the respective Faculty Advisors for further necessary actions.

**Course End Survey:** The objective of this survey is to know the attainment of the outcomes relevant to the subject, i.e., Applied Linear Algebra (MTH 3003). Please respond to the questions by clicking any one of the options against each of the questions.

| APPENDIX I – VISION |
| --- |
| The Siksha ‘O’ Anusandhan will be a leading institution of higher learning in its chosen areas of concentration, preparing future generations through quality teaching and innovative research and will emerge as a comprehensive and socially inclusive University in the country for professional advancements in related disciplines. |

| APPENDIX II – MISSION |
| --- |
| * Educate students to become responsible, enlightened, and productive citizens; * Conduct scholarship and promote entrepreneurship that improve the human condition; * Serve business, education, government, health care systems, and community; and * Enhance the cultural environment of the region. |

| APPENDIX III – PROGRAM EDUCATIONAL OBJECTIVES (PEO) | |
| --- | --- |
| 1 | Our Graduates will have successful professional careers in industry, government, academia or non-government organisations. |
| 2 | Our Graduates will effectively lead, work and communicate in multidisciplinary teams and apply sound engineering principles and design methodology to solve societal problems. |
| 3 | Our Graduates will maintain currency in their chosen field through higher study, through organizational participation and through participation in professional developmental activities. |

| APPENDIX IV – PROGRAM SPECIFIC OUTCOMES (PSO) | |
| --- | --- |
| PSO1 |  |
| PSO2 |  |
| PSO3 |  |

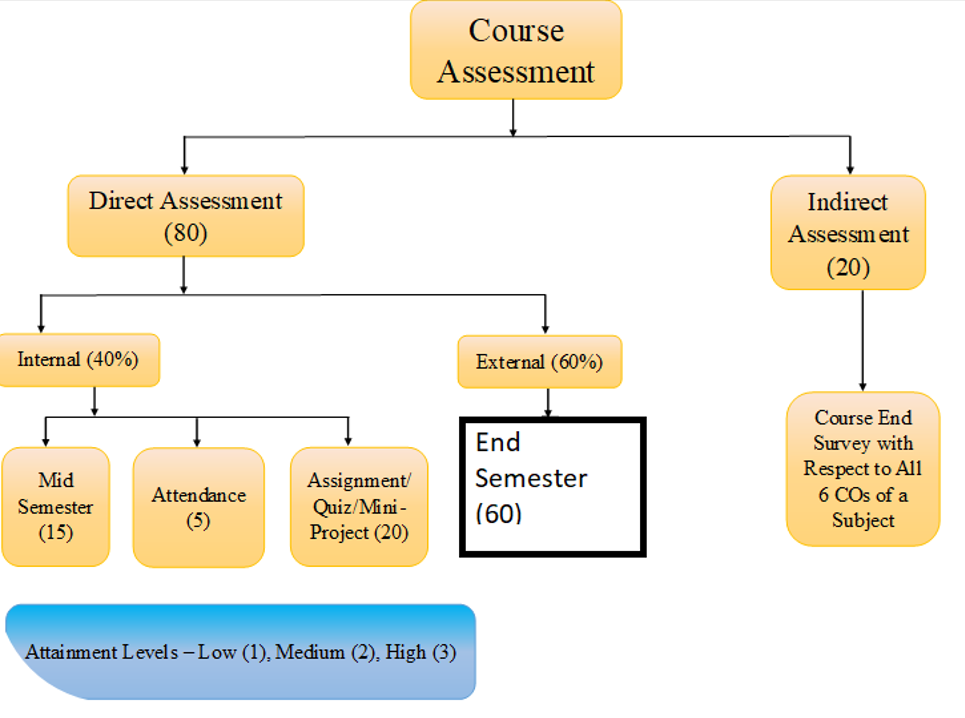
| APPENDIX V – PROGRAM OUTCOMES (PO) | |
| --- | --- |
| **POs** | **Description** |
| PO1 | **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems. |
| PO2 | **Problem analysis:** Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences. |
| PO3 | **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations. |
| PO4 | **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions. |
| PO5 | **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations. |
| PO6 | **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues, and the consequent responsibilities relevant to the professional engineering practice. |
| PO7 | **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development. |
| PO8 | **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice. |
| PO9 | **Individual and teamwork:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings. |
| PO10 | **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions. |
| PO11 | **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments. |
| PO12 | **Life-long learning:** Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change. |

| APPENDIX VI – BLOOM’S TAXONOMY |
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|  |
| --- |

In this subject, Levels 1–4 of Bloom’s Taxonomy, i.e., Remembering–Analysing are covered.

| APPENDIX VII – COURSE ASSESSMENT  (FOR GRADING PATTERN 6) |
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|  |
| --- |



| APPENDIX VIII – ATTAINMENT OF COs, POs, & PSOs |
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|  |
| --- |

| APPENDIX IX – GRADING SYSTEM |
| --- |

| **Performance** | **Letter grade** | **Grade Point Per Credit** |
| --- | --- | --- |
| Outstanding | O | 10 |
| Accomplished | A | 9.5 |
| Impressive | B | 8.5 |
| Encouraging | C | 7.5 |
| Acceptable | D | 6.5 |
| Must do better | E | 5.5 |
| Fail | F | 0 |

***PERCENTAGE EQUIVALENCE CONVERSION FOR CGPA:***

Percentage of Marks = CGPA Multiplied by 10

| APPENDIX X – 9.1.2 RELATIVE GRADING |
| --- |

| **LETTER GRADE** | **STUDENTS RANGE** | **GRADE POINT** |
| --- | --- | --- |
| O | Top 5% | 10 |
| A | Next 10% | 9.5 |
| B | Next 20% | 8.5 |
| C | Next 30% | 7.5 |
| D | Next 20% | 6.5 |
| E | Remaining Students having Numeric Score >= 40 | 5.5 |
| F | Numeric Score < 40 | 0 |

The minimum possible cutoff used for “E” grade is 40 (Internal + External), i.e., if the marks obtained are less than 40 (Internal + External) then the student won't be given an "E" grade (or above) in a particular instance of the Subject irrespective of value of cutoff for “E” grade.

The Relative Grading System will only be applicable for those subjects which follow Grading Patterns 1, 2, and 6. For Relative grading to be applicable, the number of students in the subject will need to be at least 12. Absolute Grading will be applicable otherwise.

| APPENDIX XI – 10. GRADUATION CGPA REQUIREMENTS |
| --- |

The Minimum Cumulative Grade Point Average required for Graduation is **6.0**, i.e., a student can only be considered for graduation if and only if his/her Cumulative Grade Point Average (after complying with all the requirements of the (Deemed to be University) and the Constituent College required for graduation) is **greater than or equal to 6.0 (six point zero)**.

| APPENDIX XII – 12. MINIMUM REQUIREMENTS FOR A PASSING GRADE |
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The Minimum Attendance and Numeric Score Requirements for a passing grade at Institute of Technical Education and Research (ITER), Siksha ‘O’ Anusandhan (Deemed to be University) which will be followed from admission year 2018-2019.

| **NUMERIC SCORE REQUIREMENTS** | |
| --- | --- |
| INTERNAL | 16 |
| EXTERNAL | 24 |
| TOTAL | 40 |

| **ATTENDANCE REQUIREMENTS** | |
| --- | --- |
| ATTENDANCE | 75% |

| APPENDIX XIII – 15. APPEARING THE (DEEMED TO BE UNIVERSITY) EXAM |
| --- |

The Minimum Numeric Score and Attendance Requirements for appearing the External Exam of a subject are as mentioned below.

| **NUMERIC SCORE REQUIREMENTS (For External Exam)** | |
| --- | --- |
| INTERNAL COMPONENT | 16 |

| **ATTENDANCE REQUIREMENTS (For External Exam)** | |
| --- | --- |
| ATTENDANCE | 75% |