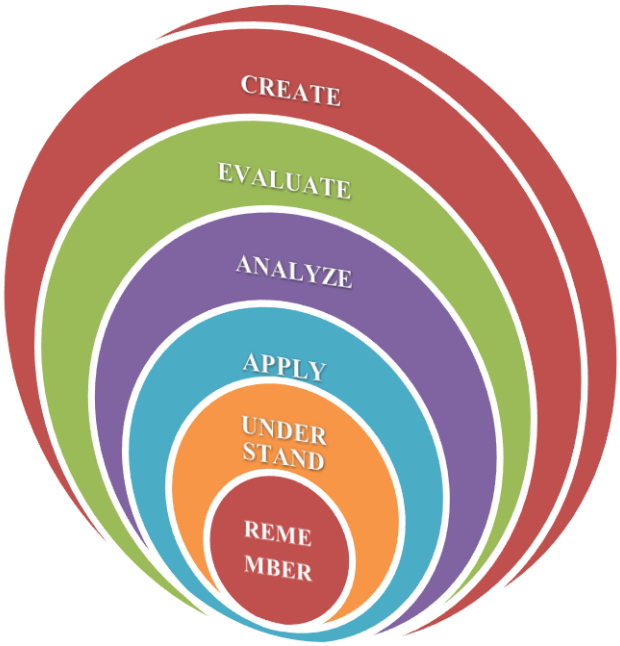
OUTCOME BASED EDUCATION BOOKLET

CIVIL ENGINEERING

B.Tech

For the Batch of Students admitted during Academic Year 2018-19



.....Moving Towards Perfection in Engineering

INSTITUTE OF AERONAUTICAL ENGINEERING
(AUTONOMOUS)
Approved by AICTE: Affiliated to JNTUH and Accredited by NAAC with 'A' Grade
Dundigal, Hyderabad - 500 043

VISION

The Vision of Civil Engineering Department is to produce eminent, competitive and dedicated Civil Engineers by imparting latest technical skills and ethical values to empower the students to play a key role in the planning and execution of infrastructural & developmental activities of the nation.

MISSION

To provide State-of-the-Art facilities for conducting experiments in the field of Civil Engineering as well as providing high quality research with latest technological knowledge so that the graduates present themselves as efficient and potential candidates for government and private sector organizations within and outside the country.

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As Per NBA Norms Post Sep, 2016

Semester: I, II, III, IV, V, VI, VII, VIII

Part - I A

PROGRAM EDUCATIONAL OBJECTIVES AND OUTCOMES

Civil Engineering Department Advisory Council:
The Civil Engineering Department Advisory Council (CEDAC) includes a diverse group of experts from academy and industry, as well as alumni representation. The Advisory council meets annually, or as needed, for a comprehensive review of the Civil Engineering Department strategic planning and programs. The Advisory Council meets with the administration, faculty and students and prepares a report, which is presented to the Principal. In each visit, the Department of Civil Engineering responds to the DAC report indicating improvements and amendments to the program.

Program Educational Objectives, Outcomes and Assessment Criteria: The "Program Educational Objectives" were initially drafted by a committee of CIVIL Engineering faculty and were vetted and approved by a group of faculty from peer department, Information Technology and the CIVIL Engineering Department Advisory Council.

1. PROGRAM EDUCATIONAL OBJECTIVES, OUTCOMES AND ASSESSMENT CRITERIA

Learning Outcomes and Assessment Criteria

The educational objectives of a module are statements of the broad intentions of the teaching team. They indicate what it is the teaching team intends to cover and the learning opportunities they intend to make available to the student. A learning outcome is a statement of what a learner (student) is expected to know, understand and/or be able to do at the end of a period of learning. It is advisable to express learning outcomes with the common prefix:

'On completion of (the period of learning e.g. module), the student **is expected to** be able to…'

Generally, learning outcomes do not specify curriculum, but more general areas of learning. It is not possible to prescribe precisely how specific a learning outcome statement should be. There is a balance to be struck between the degree of specificity in a learning outcome statement and that achieved by the assessment criteria.

If there are too many learning outcomes for a module, then either they are becoming assessment criteria or they are specifying too much curricular detail. The curriculum should be described in the range statement. Too few learning outcomes are unlikely to provide sufficient information on the course. As a guide, there should be between 3 and 4 learning outcomes for a course.

2. B. TECH - CIVIL ENGINEERING PROGRAM EDUCATIONAL OBJECTIVES

The current set of Program Educational Objectives (PEO's) for the Civil Engineering Program at IARE was developed by integrating the ideas of the Civil Engineering Faculty, students, and the Departmental Advisory Council. The Advisory Council provides representation from alumni, local employers and the professional civil engineering community.

The Program Educational Objectives so developed reflect the professional needs of Civil Engineering Program graduate.

The PEO's developed for its undergraduate program reflect commitment of the department to providing a program that produces graduates who, within four years of graduation, will:

Program Educational Objective -1: *Professional Excellence*

- To impart proficiency in engineering knowledge and skills to analyze, design, build, maintain, or improve civil engineering based systems.

Program Educational Objective -2: *Understanding Socio-Economic Aspects*

- To offer broad education and practical skills so that the students can carry out technical investigations within realistic constraints such as economic, environmental, societal, safety and sustainability.

Program Educational Objective -3: *Technical collaboration*

- To impart ability to collaborate with and function on multidisciplinary teams to offer engineering solutions to the society

Program Educational Objective -4: *Continued Self-Learning*

- To create interest in the students to engage in life-long learning in advanced areas of civil engineering and related fields.

Program Educational Objective -5: *Effective Contribution to Society*

- To educate the students in ethical values and social responsibility to use engineering techniques and modern tools necessary for civil engineering practice to serve the society effectively.

These objectives are quite broad by intention, as Civil Engineering graduates may seek further education or work in diverse areas. To make these objectives meaningful, they may be demonstrated by performance, actions, or achievements.

1. **Students will establish themselves as effective professionals by solving real problems through the use of civil engineering knowledge and with attention to team work, effective communication, critical thinking and problem solving skills. These may be demonstrated by any of the following:**

    - Acceptance by and satisfactory progress in a graduate degree program;
    - Significantly contributing to delivery of desired component, product, or process;
    - Formulating and solving moderately complex engineering problems;
    - Skillfully using state-of-the-art tools for structural engineering processes;
    - Making practical recommendations that address engineering product and system level issues;
    - Producing clear written civil engineering documentation (papers, reports, and significant parts of proposals);
    - Communicating effectively in a group environment;
    - Being asked to make presentations or reports for internal colleagues or clients;
    - Publishing refereed paper in conference or journal, or producing an internally reviewed publication;
    - Making a significant contribution to a proposal;
    - Applying for a patent or making a useful invention;
    - Participating in the field through public speaking, activity in professional societies, technical associations, standards boards, etc.

2. **Students will develop skills that prepare them for immediate employment and for life-long learning in advanced areas of Civil Engineering and related fields may be demonstrated by any of the following:**

- Successfully completing a course for B. Tech;
- Successfully completing a tutorial at a conference;
- Learning a new skill, civil engineering application software's;
- Reading technical books, journals, conference papers, technical reports, or standards;
- Attending a technical conference, symposium, or workshop;
- Belonging to a professional society;

3. **Students will demonstrate their ability to adapt to a rapidly changing environment by having learned and applied new skills and new technologies may be demonstrated by any of the following:**

    - Appropriately using tools for collaborating with Design and construction consultancy companies;
    - Skillfully using tools for project and configuration management, e.g., resource planning systems, software source control systems, etc;
    - Making appropriate decisions on when to outsource, when to use off-the-shelf components, and when to develop components in-house;
    - Seeking assistance or elevating problems when necessary;
    - Properly handling a situation involving intellectual property rights;

4. **Students will be provided with an educational foundation that prepares them for excellence, leadership roles along diverse career paths with encouragement to professional ethics and active participation needed for a successful career by the following any one:**

    - Leading a project or design team;
    - Working successfully on ethnically, technically, or gender diverse teams;
    - Effectively resolving problems encountered in team work;
    - Estimating correctly the required resources (time, team, equipment, etc.) for civil engineering projects;
    - Promotion to managerial position;
    - Election or appointment to leadership position in a professional society;
    - Delegating effectively;
    - Participating in one of your organization's NSS programs;
    - Volunteering in a college, civic, or other charitable organization;
    - Participating in team sports or coaching;
    - Accounting for larger societal, legal, business, and technical context while making decisions on a project;
    - Properly handling a situation involving ethics;

3. B. Tech – CIVIL ENGINEERING PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOME

A graduate of the Civil Engineering Program will demonstrate:

PROGRAM OUTCOMES:

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 analyze 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 modeling 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 team work**: 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.

B.TECH PROGRAM SPECIFIC OUTCOMES (PSO's)

The Program Specific outcomes (PSO's) listed below were developed specifically to help the aforementioned Program Educational Objectives (PEO's) are met. The focus of these PSO's is consistent with the set of required PO's identified in the NBA accreditation guidelines. Minimum NBA requirements have been supplemented with Program Specific Outcomes that address the uniqueness of a IARE civil engineering education.

The Civil Engineering PSO's require that graduates receiving a Bachelor of Technology in Civil Engineering degree from IARE demonstrate the following.

PSO1. ENGINEERING KNOWLEDGE: Graduates shall demonstrate sound knowledge in analysis, design, laboratory investigations and construction aspects of civil engineering infrastructure, along with good foundation in mathematics, basic sciences and technical communication.

PSO2. BROADNESS AND DIVERSITY: Graduates will have a broad understanding of economical, environmental, societal, health and safety factors involved in infrastructural development, and shall demonstrate ability to function within multidisciplinary teams with competence in modern tool usage.

PSO3. SELF-LEARNING AND SERVICE: Graduates will be motivated for continuous self-learning in engineering practice and/or pursue research in advanced areas of civil engineering in order to offer engineering services to the society, ethically and responsibly.

These **PEO's** and **PSO's** represent a formal manifestation of an educational philosophy and spirit that the Civil Engineering Department has operated under for many years.

4. MAPPING OF PROGRAM EDUCATIONAL OBJECTIVES TO PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

The following Figure 1 shows the correlation between the PEOs and the POs and PSOs

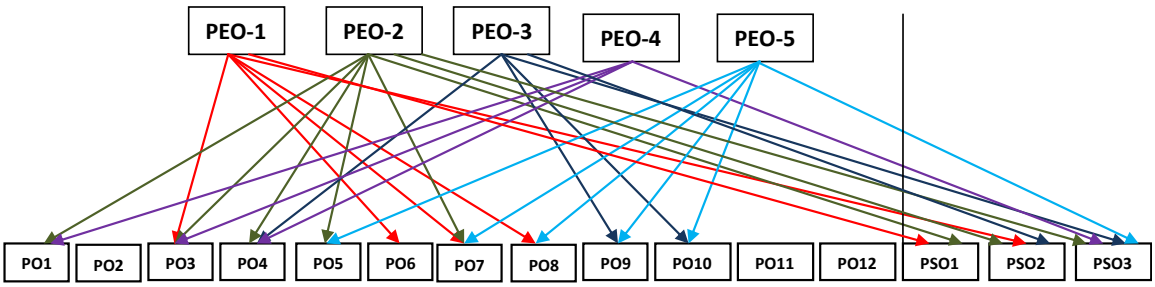

Figure 1: Correlation between the PEOs and the POs and PSOs

The following Table shows the correlation between the Program Educational Objectives and the Program Outcomes & Program Specific Outcomes

Table 1: Correlation between the Program Educational Objectives and the Program Outcomes & Program Specific Outcomes

Program Educational Objectives	Program Outcomes
Program Educational Objective -1 *To impart proficiency in engineering knowledge and skills to analyze, design, build, maintain, or improve civil engineering based systems*	**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. **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.

PSO1. Engineering Knowledge: Graduates shall demonstrate sound knowledge in analysis, design, laboratory investigations and construction aspects of civil engineering infrastructure, along with good foundation in mathematics, basic sciences and technical communication.

PSO2. Broadness and Diversity: Graduates will have a broad understanding of economical, environmental, societal, health and safety factors involved in infrastructural development, and shall demonstrate ability to function within multidisciplinary teams with competence in modern tool usage

Program Educational Objective -2

To offer broad education and practical skills so that the students can carry out technical investigations within realistic constraints such as economic, environmental, societal, safety and sustainability.

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

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 modeling to complex engineering activities with an understanding of the limitations.

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.

PO9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PSO1. Engineering Knowledge: Graduates shall demonstrate sound knowledge in analysis, design, laboratory investigations and construction aspects of civil engineering infrastructure, along with good foundation in mathematics, basic sciences and technical communication.

PSO2. Broadness and Diversity: Graduates will have a broad understanding of economical, environmental, societal, health and safety factors involved in infrastructural development, and shall demonstrate ability to function within multidisciplinary teams with

	competence in modern tool usage **PSO3. Self-Learning and Service**: Graduates will be motivated for continuous self-learning in engineering practice and/or pursue research in advanced areas of civil engineering in order to offer engineering services to the society, ethically and responsibly.
Program Educational Objective -3 *To impart ability to collaborate with and function on multidisciplinary teams to offer engineering solutions to the society*	**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. **PO9: Individual and team work**: 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. **PSO2. Broadness and Diversity:** Graduates will have a broad understanding of economical, environmental, societal, health and safety factors involved in infrastructural development, and shall demonstrate ability to function within multidisciplinary teams with competence in modern tool usage **PSO3. Self-Learning and Service**: Graduates will be motivated for continuous self-learning in engineering practice and/or pursue research in advanced areas of civil engineering in order to offer engineering services to the society, ethically and responsibly.
Program Educational Objective -4 *To create interest in the students to engage in life-long learning in advanced areas of civil engineering and related fields.*	**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 analyze 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.

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.

PSO3. Self-Learning and Service: Graduates will be motivated for continuous self-learning in engineering practice and/or pursue research in advanced areas of civil engineering in order to offer engineering services to the society, ethically and responsibly.

Program Educational Objective -5

To educate the students in ethical values and social responsibility to use engineering techniques and modern tools necessary for civil engineering practice to serve the society effectively.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

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 team work: 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.

PSO3. Self-Learning and Service: Graduates will be motivated for continuous self-learning in engineering practice and/or pursue research in advanced areas of civil engineering in order to offer engineering services to the society, ethically and responsibly..

5. RELATION BETWEEN THE PROGRAM OUTCOMES AND PROGRAM EDUCATIONAL OBJECTIVES.

The following Table 2 shows the correlation between the PEOs and the Program Outcomes

Table 2: Relationships between Program Educational Objectives and Program Outcomes

Program Outcomes	PEO 1	PEO 2	PEO3	PEO4	PEO5
PO1: Engineering knowledge	--	2:Medium	--	2:Medium	--
PO2: Problem analysis	--	--	--	3:High	--
PO3: Design/development of solutions	3.High	2:Medium	--	2:Medium	--
PO4: Conduct investigations of complex problems	--	2:Medium	2:Medium	2:Medium	--
PO5: Modern tool usage	--	2:Medium	--	--	2:Medium
PO6: The engineer and society	2:Medium	--	--	--	--
PO7: Environment and sustainability	3:High	1:Low	--	--	2:Medium
PO8: Ethics	1:Low	--	--	--	2:Medium
PO9: Individual and team work	--	3:High	3:High	--	2:Medium
PO10: Communication	--	--	1:Low	--	1:Low
PO11: Project management and finance	--	--	2:Medium	--	1:Low
PO12: Life-long learning	--	--	--	1:Low	--

Note: PEO_1, PEO_2, PEO_n are distinct elements. Enter correlation levels 1,2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

RELATION BETWEEN THE PROGRAM SPECIFIC OUTCOMES AND THE PROGRAM EDUCATIONAL OBJECTIVES

The following Table shows the correlation between the PEO's and the PSO's

Table 4: Relationships between program Educational Objectives and program Specific Outcomes

	PEO1:	PEO2:	PEO3:	PEO4:	PEO5:
PSO1:	3: High	2: Medium			
PSO2:	2: Medium	3: High	1: Low		
PSO3:			3: High	2: Medium	1: Low

Note: PEO_1, PEO_2 PEO_n are distinct elements. Enter correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Note:

- The assessment process can be direct or indirect.
- The direct assessment will be through interim assessment by the faculty or by industry / technology experts.

- The indirect assessment on the other hand could be by students through course outcomes, lab evaluation, department associations, exit interviews, engineering services, GATE etc.
- Frequency of assessment can be once in a semester and justified by the programme coordinator.

6. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES OF (B.TECH) CIVIL GRADUATES

Graduates from accredited programmes must achieve the following learning outcomes, defined by the broad areas of learning.

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

- Knowledge and understanding of scientific principles and methodology necessary to strengthen their education in their engineering discipline, to enable appreciation of its scientific and engineering context, and to support their understanding of historical, current, and future developments and technologies;
- Knowledge and understanding of mathematical principles necessary to underpin their education in their engineering discipline and to enable them to apply mathematical problems;
- Ability to apply and integrate knowledge and understanding of other engineering disciplines to support study of their own engineering discipline.

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

- Is based on the problem solving process that has been well documented in engineering texts. The elements of the process include:
    - Problem or opportunity identification
    - Problem statement and system definition
    - Problem formulation and abstraction
    - Information and data collection
    - Model translation
    - Validation
    - Experimental design
    - Solution development or experimentation
    - Interpretation of results
    - Implementation and documentation

As most engineers eventually learn, the problem solving process is never complete. Therefore, a final element here is feedback and improvement.

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.

Design is the creation and development of an economically viable product, process or system to meet a defined need. It involves significant technical and intellectual challenges and can be used to integrate all engineering understanding, knowledge and skills to the solution of real problems. Graduates will therefore need the knowledge, understanding and skills to:

- Investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues;

- Understand customer and user needs and the importance of considerations such as aesthetics;
- Identify and manage cost drivers;
- Use creativity to establish innovative solutions;
- Ensure fitness for purpose of all the aspects of the problem including production, operation, maintenance and disposal of the product;
- Manage the design process and evaluate the outcomes;

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.

Practical application of engineering skills, combining theory and experience, and use of other relevant knowledge and skills. This can include:

- Knowledge of characteristics of particular materials, equipment, processes, or products;
- Workshop and laboratory skills;
- Understanding of contexts in which engineering knowledge can be applied (for example, operations and management, technology development, etc.);
- Understanding use of technical literature and other information sources Awareness of nature of intellectual property and contractual issues;
- Understanding of appropriate codes of practice and industry standards;
- Awareness of quality issues;
- Ability to work with technical uncertainty;
- Understanding of engineering principles and the ability to apply them to analyses key engineering processes;
- Ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modeling techniques;
- Ability to apply quantitative methods and computer software relevant to their engineering discipline, in order to solve engineering problems;
- Understanding of and ability to apply a systems approach to engineering problems;

PO5: Modern tool usage - Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

- Encompasses a wide range of tools and skills needed by engineering graduates including computer software, simulation packages, diagnostic equipment and use of technical library resources and literature search tools.

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.

- Here the focus is on “knowledge” and is interpreted to mean the student’s obtaining in-depth knowledge of on contemporary issues. Three types of examples are given – socio economic, political and environmental excluding contemporary, technical engineering issues.

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.

- Understanding of the requirement for engineering activities to promote sustainable development;
- Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk (including environmental risk) issues;

- Assess the effects of the engineering products or solutions provided to solve real-world problems within the context of applicable environment;

PO8: Ethics - Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

- Understanding the need for a high level of professional and ethical conduct in engineering.
- Comprises four components: ability to make informed ethical choices, knowledge of professional codes of ethics, evaluates the ethical dimensions of professional practice, and demonstrates ethical behavior;
- Stood up for what he/she believed in;
- High degree of trust and integrity;

PO9: Individual and team work - Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

- Independence;
- Maturity – requiring only the achievement of goals to drive their performance;
- Self-direction (take a vaguely defined problem and systematically work to resolution);
- Teams are used during the classroom periods, in the hands-on labs, and in the design projects;
- Instruction on effective teamwork and project management is provided along with an appropriate textbook for reference;
- Teamwork is important not only for helping the students know their peers but also in completing assignments;
- Subjective evidence from senior students shows that the friendships and teamwork extends into the Junior years, and for some of those students, the friendships continues into the workplace after graduation;
- Ability to work with all levels of people in an organization;
- Ability to get along with others;
- Demonstrated ability to work well with a team;

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.

"Students should demonstrate the ability to communicate effectively in writing."

a. Clarity
b. Grammar/Punctuation
c. References

Verbal Communication: "Students should demonstrate the ability to communicate effectively orally."

a. Speaking Style
b. Subject Matter

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 as a leader in a team, to manage projects and in multidisciplinary environments.

- Knowledge of management techniques which may be used to achieve engineering objectives within that context;
- Knowledge and understanding of commercial and economic context of engineering processes;

- Understand the criteria in context of the product, application and users to deliver an effaceable project management process;
- Identify suitable management strategies and apply standard processes and procedures to achieve productive and conclusive effort;

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.

- Inspire the students to further explore in his/her program to recognize the need for life-long learning. Some aspects of life-long learning:
    - Project management professional certification
    - MBA
    - Begin work on advanced degree
    - Keeping current in CSE and advanced engineering concepts
    - Personal continuing education efforts
    - Ongoing learning – stays up with industry trends/ new technology
    - Continued personal development
    - Have learned at least 2-3 new significant skills
    - Have taken up to 80 hours (2 wks) training per year

PROGRAM SPECIFIC OUTCOMES OF (B.Tech) CIVIL GRADUATES

PSO1. ENGINEERING KNOWLEDGE

Graduates shall demonstrate sound knowledge in analysis, design, laboratory investigations and construction aspects of civil engineering infrastructure, along with good foundation in mathematics, basic sciences and technical communication.

Performance Criteria Definitions

- Problem or opportunity identification
- Problem formulation and abstraction
- Information and data collection.
- Model translation
- Experimental design and solution development.
- Implementation and documentation.

PSO2. BROADNESS AND DIVERSITY

Graduates will have a broad understanding of economical, environmental, societal, health and safety factors involved in infrastructural development, and shall demonstrate ability to function within multidisciplinary teams with competence in modern tool usage.

Performance Criteria Definitions

- Problem or opportunity identification
- Problem formulation and abstraction
- Information and data collection.
- Model translation
- Experimental design and solution development.
- Implementation and documentation.

PSO3. SELF-LEARNING AND SERVICE

Graduates will be motivated for continuous self-learning in engineering practice and/or pursue research in advanced areas of civil engineering in order to offer engineering services to the society, ethically and responsibly.

Performance Criteria Definitions

- Investigate and define a problem and identify constraints relating to health, safety,

environmental and sustainability and assessment of risks based on these constraints.

- Understand customer and user needs and the importance of considerations such as aesthetics Identify and manage costs and drivers thereof.
- Use creativity to establish innovative solution Ensure fitness of purpose, for all aspects of the problem including production, operation, maintenance and disposal.
- Manage the design process and evaluate outcomes.

Courses offered in Civil Engineering Curriculum (IARE-R18) –Vs- Program Outcomes and Program Specific Outcomes Attained through course modules for I, II Semesters

Code	Subject	Program Outcomes (PO)												Program Specific Outcomes (PSO)		
		01	02	03	04	05	06	07	08	09	10	11	12	01	02	03
I Semester																
AHSB01	English									√	√	√			√	
AHSB02	Linear Algebra and Calculus	√	√											√		
AEEB01	Fundamentals of Electrical Engineering	√	√	√			√								√	
AHSB08	English Language and Communication Skills Laboratory									√	√	√			√	
AEEB05	Engineering Graphics and Design Laboratory	√							√					√		
AMEB02	Fundamentals of Electrical Engineering Laboratory	√	√	√			√								√	
II Semester																
AHSB11	Mathematical Transform Techniques	√	√		√									√		
AHSB03	Engineering Chemistry	√	√		√			√						√		
AHSB04	Waves and Optics	√	√		√									√		
ACSB01	Programming for Problem Solving	√	√	√		√							√	√	√	√
AHSB09	Engineering Chemistry Laboratory	√	√		√			√						√		
AHSB10	Engineering Physics Laboratory	√	√		√									√		
ACSB02	Programming for Problem Solving Laboratory	√	√	√		√							√	√	√	√
AMEB01	Workshop/ Manufacturing Practices Laboratory	√		√										√	√	

7. PROCEDURES FOR OUTCOME DELIVERY AND ASSESSMENT WITH RESPECT TO PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

The categorization of the Program Outcomes and Program Specific Outcomes of the above Civil Engineering courses is grouped as follows:

Code	Subject	Code	Subject
PO1: Engineering knowledge - Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.			
AHSB02	Linear Algebra and Calculus	AEEB01	Fundamentals of Electrical Engineering
AEEB05	Engineering Graphics and Design Laboratory	AMEB02	Fundamentals of Electrical Engineering Laboratory
AHSB11	Mathematical Transform Techniques	AHSB03	Engineering Chemistry

Code	Subject	Code	Subject
AHSB04	Waves and Optics	ACSB01	Programming for Problem Solving
AHSB09	Engineering Chemistry Laboratory	AHSB10	Engineering Physics Laboratory
ACSB02	Programming for Problem Solving Laboratory	AMEB01	Workshop/ Manufacturing Practices Laboratory
PO2: Problem analysis - Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.			
AHSB02	Linear Algebra and Calculus	AEEB01	Fundamentals of Electrical Engineering
AMEB02	Fundamentals of Electrical Engineering Laboratory	ACSB02	Programming for Problem Solving Laboratory
AHSB11	Mathematical Transform Techniques	AHSB03	Engineering Chemistry
AHSB04	Waves and Optics	ACSB01	Programming for Problem Solving
AHSB09	Engineering Chemistry Laboratory	AHSB10	Engineering Physics Laboratory
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.			
AEEB01	Fundamentals of Electrical Engineering	AMEB02	Fundamentals of Electrical Engineering Laboratory
ACSB01	Programming for Problem Solving	ACSB02	Programming for Problem Solving Laboratory
AMEB01	Workshop/ Manufacturing Practices Laboratory		
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.			
AHSB11	Mathematical Transform Techniques	AHSB03	Engineering Chemistry
AHSB04	Waves and Optics	AHSB09	Engineering Chemistry Laboratory
AHSB10	Engineering Physics Laboratory		
PO5: Modern tool usage - Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.			
ACSB01	Programming for Problem Solving	ACSB02	Programming for Problem Solving Laboratory
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.			
AEEB01	Fundamentals of Electrical Engineering	AMEB02	Fundamentals of Electrical Engineering Laboratory
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.			
AHSB03	Engineering Chemistry	AHSB09	Engineering Chemistry Laboratory
PO8: Ethics - Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.			
AEEB05	Engineering Graphics and Design Laboratory		

Code	Subject	Code	Subject
PO9: Individual and team work - Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.			
AHSB01	English	AHSB08	English Language and Communication Skills Laboratory
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.			
AHSB01	English	AHSB08	English Language and Communication Skills Laboratory
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.			
AHSB01	English	AHSB08	English Language and Communication Skills Laboratory
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.			
ACSB01	Programming for Problem Solving	ACSB02	Programming for Problem Solving Laboratory
PSO1: ENGINEERING KNOWLEDGE: Graduates shall demonstrate sound knowledge in analysis, design, laboratory investigations and construction aspects of civil engineering infrastructure, along with good foundation in mathematics, basic sciences and technical communication.			
AHSB02	Linear Algebra and Calculus	AEEB05	Engineering Graphics and Design Laboratory
AHSB11	Mathematical Transform Techniques	AHSB03	Engineering Chemistry
AHSB04	Waves and Optics	ACSB01	Programming for Problem Solving
AHSB09	Engineering Chemistry Laboratory	AHSB10	Engineering Physics Laboratory
ACSB02	Programming for Problem Solving Laboratory	AMEB01	Workshop/ Manufacturing Practices Laboratory
PSO2: BROADNESS AND DIVERSITY: Graduates will have a broad understanding of economical, environmental, societal, health and safety factors involved in infrastructural development, and shall demonstrate ability to function within multidisciplinary teams with competence in modern tool usage			
AHSB01	English	AEEB01	Fundamentals of Electrical Engineering
AHSB08	English Language and Communication Skills Laboratory	AMEB02	Fundamentals of Electrical Engineering Laboratory
ACSB01	Programming for Problem Solving	ACSB02	Programming for Problem Solving Laboratory
AMEB01	Workshop/ Manufacturing Practices Laboratory		
PSO3: SELF-LEARNING AND SERVICE: Graduates will be motivated for continuous self-learning in engineering practice and/or pursue research in advanced areas of civil engineering in order to offer engineering services to the society, ethically and responsibly.			
ACSB01	Programming for Problem Solving	ACSB02	Programming for Problem Solving Laboratory

8. METHODS OF MEASURING LEARNING OUTCOMES AND VALUE ADDITION

Methodologies that are used to measure student learning each have their own limitations and biases, and no method can be counted on to be completely error free. That is why best practice in educational research dictates triangulating the data. If several different sources of data are used, it

increases the probability that the findings present an accurate picture. We employ the following formal assessment procedures:

1) End-of-semester course evaluations
2) Departmental mid-semester course evaluations
3) Departmental course objective surveys
4) Course portfolio evaluations
5) Exit Interviews
6) Alumni feedback
7) Employer surveys
8) Department academic council meetings
9) Faculty meetings
10) Project work
11) Job Placements

Each is described in more detail below:

1) ***End-of-semester course evaluations:*** The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into FIVE units and each unit carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with 'either' 'or' choice will be drawn from each unit. Each question carries 14 marks. There could be a maximum of three sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept
30 %	To test the analytical skill of the concept
20 %	To test the application skill of the concept

2) ***Departmental mid-semester course evaluations***: For each theory course the mid semester shall be conducted by the faculty/teacher handling the course. Mid semester is conducted for a total of 30 marks, with 25 marks for Continuous Internal Examination (CIE) and 05 marks for Quiz / Alternative Assessment Tool (AAT).

Continuous Internal Examination (CIE): Two CIE exams shall be conducted at the end of the 8^{th} and 17^{th} week of the semester respectively. The CIE exam is conducted for 25 marks of 2 hours duration consisting of two parts. Part–A shall have five compulsory questions of one mark each. In part–B, four out of five questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams. The valuation and verification of answer scripts of CIE exams shall be completed within a week after the conduct of the Internal Examination.

Quiz / Alternative Assessment Tool (AAT): Two Quiz exams shall be online examination consisting of 20 multiple choice questions and are be answered by choosing the correct answer from a given set of choices (commonly four). Such a question paper shall be useful in the testing of knowledge, skills, application, analysis, evaluation and understanding of the students. Marks shall be awarded considering the average of two quizzes for every course.

In order to encourage innovative methods while delivering a course, the faculty members have been encouraged to use the Alternative Assessment Tool (AAT) in place of two quizzes. This AAT enables faculty to design own assessment patterns during the CIA. However, the usage of AAT is completely optional. The AAT enhances the autonomy (freedom and flexibility) of individual faculty and enables them to create innovative pedagogical practices. If properly applied, the AAT converts the classroom into an effective learning centre. The AAT may include seminars, assignments, term paper, open ended experiments, micro-

projects, five minutes video, MOOCs etc.

However, it is mandatory for a faculty to obtain prior permission from the concerned HOD and spell out the teaching/assessment pattern of the AAT prior to commencement of the classes.

3) ***Departmental course objective surveys:*** The Civil Engineering department conducts end-of-semester course objective surveys for all of our courses. All departmental students are encouraged to fill out a brief survey on the state of the courses they are currently taking, and space is provided for a written comment. Faculty are strongly encouraged to review these evaluations, and draft a brief response on how they will react to correct any deficiencies noted by the students. The results are reviewed by the departmental faculty (all faculty have permission to read results for all courses). The results of how courses satisfy their objectives are discussed at a faculty meeting.

4) ***Course portfolio evaluations:*** We collect course portfolios of each course offered in the given semester from the instructor. They remain on file for our entire faculty to study. These portfolios help the course coordinator monitor how the course is being taught, and help new faculty understand how more experienced colleagues teach the given course. With respect to the assessment, each portfolio contains two surveys to be filled out by the instructor of the course. The beginning-of-semester survey encourages faculty members to think about what they can do to improve the teaching and administration of their course, compared with the last time they taught it. The end-of-semester survey encourages faculty to record what did and did not work well during this course offering and what changes should be made for the future.

5) ***Exit Interviews:*** Inputs from final year students are solicited annually through Civil Engineering Exit Survey. The results are disseminated to the faculty and department advisory council for analysis and discussion. The questionnaire is designed to survey program outcomes, solicit about program experiences, career choices as well as suggestions and comments. This instrument seeks to assess how students view the department's program in retrospect.

6) ***Alumni feedback:*** The alumni survey is a written questionnaire which alumni are asked to complete. We use this survey seeking input on the Program Objectives and Learning Outcomes based on their experience after graduation and after they have spent time in the working world. Alumni are an excellent resource with perspective on the value and advantages of their education. They are also resource for current students for potential networking and employment. The data will be analyzed and used in continuous improvement.

7) ***Employer surveys:*** The employer survey is a written questionnaire which employers of the program's graduates are asked to complete. We review the effectiveness of our curriculum and how well the student is prepared in the department of Civil Engineering. To do this, we survey Employers and Advisors of alumni who graduated four years ago. We ask about several categories of preparation, and for each category, how well does they think he or she was prepared, and how important you think preparation in that area is to him or her in the current position. This survey will greatly assist us in determining the college overall level of achievement of our Program Educational Objectives.

8) ***Department academic council meetings:*** The Civil Engineering Department Advisory Council (CEDAC) include a diverse group of experts from academe and industry, as well as alumni representation. The Advisory Board meets annually, or as needed, for a comprehensive review of the Civil Engineering department strategic planning and programs. The Advisory Council meets with administration, faculty and students and prepares a report, which is presented to principal. In each visit, the Department of Civil Engineering responds to the report indicating improvements and amendments to the program.

9) ***Faculty meetings:*** The state of undergraduate program is always on the agenda at the monthly meeting of the faculty. The faculty devotes a substantial amount of time to formal and informal discussions assessing the state of program and searching for improvements.

10) ***Project work:*** In the non-FSI (Full Semester Internship) Model, the project work shall be evaluated for 100 marks out of which 30 marks for internal evaluation and 70 marks for semester end evaluation. The project work shall be spread over in VII semester and in VIII semester. The project work shall be somewhat innovative in nature, exploring the research bent of the mind of the student. A project batch shall comprise not more than three students. At the end of VII semester, students should submit synopsis summarizing the work done in VII semester. The project is expected to be completed by the end of VIII semester. In VII semester, a first mid review is conducted by Project Review Committee (PRC) (on the progress) for 10 marks. In VIII semester, a second mid review is conducted by PRC (on the progress) for 10 marks. On completion of the project, a third evaluation is conducted for award of internal marks of another 10 marks before the report is submitted, making the total internal marks 30. The end semester examination shall be based on the report submitted and a viva-voce exam for 70 marks by a committee comprising the Head of the department, project supervisor and an external examiner nominated by the Principal. A minimum of 40% of maximum marks shall be obtained to earn the corresponding credits.

11) ***Job Placements:*** Data from the Placement and Training Centre on graduates' job placement reflects how successful our graduates are in securing a job in a related field.

Part - II

METHODOLOGY FOR PREPARATION AND ASSESSMENT OF COURSE LEVEL STUDENT LEARNING OUTCOMES

Although the term "Expected Learning Outcome" may be new, the process of identifying the key concepts or skills that students are expected to learn during specific courses is not. Many people are more familiar with the terms "course objective" or "course competency". Expected learning outcomes are really very similar to both of these concepts. So if course objectives or competencies are available, the process of having expected learning outcomes for class is closer.

This will provide information on exactly what expected learning outcomes are and what methods can be used to assess them. This is designed to assist faculty with the process of developing expected learning outcomes and methods for assessing those outcomes in their courses. This provides basic information related to (1) course purpose; (2) expected learning outcomes; (3) methods for assessing expected learning outcomes; (4) criteria for grade determination; and (5) a course outline.

Expected Learning Outcomes:

After reading and completing this, individuals will be able to:

- Prepare a description of the course as well as a written statement regarding the course's purpose;
- Construct/develop expected learning outcomes for the course;
- Create an assessment plan that outlines the specific methods that will be used to assess the expected student learning outcomes for a course;
- Describe how grades will be determined in a process that is separate and distinct from assessing the expected learning outcomes;
- Identify the common components of a course outline ;
- Revise their course syllabi to incorporate a course purpose, expected learning outcomes, methods to assess those outcomes, the criteria for grade determination, and a course outline;
- This process uses some terminology related to the expected learning outcomes and assessment. A brief glossary of terms has been provided below for reference purposes;

Assessment of expected learning outcomes:

The process of investigating

a) What students are learning?
b) How well they are learning it in relation to the stated expected learning outcomes for the course?

Assessment plan:

The proposed methods and timeline for assessment-related activities in a given course (e.g., when are you going to check what/how well the students are learning and how are you going to do that?).

Classroom Assessment Technique (CAT): Angelo and Cross (1993) developed a variety of techniques/activities than can be used to assess students' learning. These CATs are often done anonymously and are not graded. These activities check on the class' learning while students are still engaged in the learning process. An example of a CAT is a non-graded quiz given a few weeks before the first exam.

Course description:

A formal description of the material to be covered in the course.

Course purpose:
The course purpose describes the intent of the course and how it contributes to the programme. The course purpose goes beyond the course description.

Expected learning outcome:
A formal statement of what students are expected to learn in a course (synonyms for "expected learning outcome" include learning outcome, learning outcome statement, and student learning outcome).

Evaluation:
Making a judgment about the quality of student's learning/work and assigning marks based on that judgment. Evaluation activities (such as exams, papers, etc.) are often seen as formal ways to assess the expected learning outcomes for a course.

Methods for assessing student learning outcomes:
This term refers to any technique or activity that is used to identify what students are learning or how well they are learning. Formal methods for evaluating student learning outcomes include Continuous Assessment Tests, Mid Semester Test, Tutorials, End Semester Examination etc. The assessment methods are used to identify how the well students have acquired the learning outcomes for the course.

1. COURSE PURPOSE

One of the first steps in identifying the expected learning outcomes for a course is identifying the *purpose* of teaching in the course. By clarifying the purpose of the course, faculty can help discover the main topics or themes related to students' learning. These themes help to outline the expected learning outcomes for the course.

The course purpose involves the following:

a) What role does this course play within the programme?
b) How is the course unique or different from other courses?
c) Why should/do students take this course? What essential knowledge or skills should they gain from this experience?
d) What knowledge or skills from this course will students need to have mastered to perform well in future classes or jobs?
e) Why is this course important for students to take?

The "Course Description" provides general information regarding the topics and content addressed in the course, the "Course Purpose" goes beyond that to describe how this course fits in to the students' educational experience in the programme.

2. EXPECTED LEARNING OUTCOMES

Expected Learning Outcome (definition)
An expected learning outcome is a formal statement of what students are expected to learn in a course. Expected learning outcome statements refer to specific knowledge, practical skills, areas of professional development, attitudes, higher-order thinking skills, etc. that faculty members expect students to develop, learn, or master during a course (Suskie, 2004). Expected learning outcomes are also often referred to as "learning outcomes", "student learning outcomes", or "learning outcome statements".

Simply stated, expected learning outcome statements describe:

1. What faculty members want students to *know* at the end of the course?
2. What faculty members want students *to be able to do* at the end of the course?

Learning outcomes have three major characteristics

1. They specify an action by the students/learners that is *observable;*
2. They specify an action by the students/learners that is *measurable;*
3. They specify an action that is done by the *students/learners* (rather than the faculty members);

Effectively developed expected learning outcome statements should possess all three of these characteristics. When this is done, the expected learning outcomes for a course are designed so that they can be assessed (Suskie, 2004).

3. TO DEFINE EFFECTIVE LEARNING OUTCOME STATEMENTS

When stating expected learning outcomes, it is important to use verbs that describe exactly what the learner(s) will be able to *do* upon completion of the course.

Examples of good action words to include in expected learning outcome statements:

Compile, identify, create, plan, revise, analyze, design, select, utilize, apply, demonstrate, prepare, use, compute, discuss, explain, predict, assess, compare, rate, critique, outline, or evaluate

There are some verbs that are unclear in the context of an expected learning outcome statement (*e.g., know, be aware of, appreciate, learn, understand, comprehend*). These words are often vague, have multiple interpretations, or are simply difficult to observe or measure (American Association of Law Libraries, 2005). As such, it is best to avoid using these terms when creating expected learning outcome statements.

For example, please look at the following learning outcomes statements:

- *The students will understand basic Designing techniques .*
- *The students will appreciate knowledge discovery from field reports.*

Both of these learning outcomes are stated in a manner that will make them difficult to assess. Consider the following:

- *How do you observe someone "understanding" a theory or "appreciating" designing techniques?*
- *How easy will it be to measure "understanding" or "appreciation"?*

These expected learning outcomes are more effectively stated the following way:

- *The students will be able to identify and describe what techniques are used to extract knowledge from the field reports.*
- *The students will be able to identify the characteristics of Classification techniques from the designing and the analysis.*

Incorporating Critical Thinking Skills into Expected Learning Outcomes Statements

Many faculty members choose to incorporate words that reflect critical or higher-order thinking into their learning outcome statements. Bloom (1956) developed a taxonomy outlining the different types of thinking skills people use in the learning process. Bloom argued that people use different levels of thinking skills to process different types of information and situations. Some of these are basic cognitive skills (such as memorization) while others are complex skills (such as creating new ways to apply information). These skills are often referred to as *critical thinking skills* or *higher-order thinking skills*.

Bloom proposed the following taxonomy of thinking skills. All levels of Bloom's taxonomy of thinking skills can be incorporated into expected learning outcome statements. Recently, Anderson and Krathwohl (2001) adapted Bloom's model to include language that is oriented towards the language used in expected learning outcome statements. A summary of Anderson and Krathwohl's revised version of Bloom's taxonomy of critical thinking is provided below.

Figure 3: List of Action Words (Ref: Revised Version of Bloom's Taxonomy)

REMEMBER	UNDERSTAND	APPLY	ANALYZE	EVALUATE	CREATE
Count	Associate	Add	Analyze	Appraise	Categorize
Define	Compute	Apply	Arrange	Assess	Combine
Describe	Convert	Calculate	Breakdown	Compare	Compile
Draw	Defend	Change	Combine	Conclude	Compose
Identify	Discuss	Classify	Design	Contrast	Create
Label	Distinguish	Complete	Detect	Criticize	Drive
List	Estimate	Compute	Develop	Critique	Design
Match	Explain	Demonstrate	Diagram	Determine	Devise
Name	Extend	Discover	Differentiate	Grade	Explain
Outline	Extrapolate	Divide	Discriminate	Interpret	Generate
Point	Generalize	Examine	Illustrate	Judge	Group
Quote	Give examples	Graph	Infer	Justify	Integrate
Read	Infer	Interpolate	Outline	Measure	Modify
Recall	Paraphrase	Manipulate	Point out	Rank	Order
Recite	Predict	Modify	Relate	Rate	Organize
Recognize	Rewrite	Operate	Select	Support	Plan
Record	Summarize	Prepare	Separate	Test	Prescribe
Repeat		Produce	Subdivide		Propose
Reproduce		Show	Utilize		Rearrange
Select		Solve			Reconstruct
State		Subtract			Related
Write		Translate			Reorganize
		Use			Revise
					Rewrite
					Summarize
					Transform
					Specify

Definitions of the different levels of thinking skills in Bloom's taxonomy

1) **Remember** – recalling relevant terminology, specific facts, or different procedures related to information and/or course topics. At this level, a student can remember something, but may not really understand it.
2) **Understand** – the ability to grasp the meaning of information (facts, definitions, concepts, etc.) that has been presented.
3) **Apply** – being able to use previously learned information in different situations or in problem solving.
4) **Analyze** – the ability to break information down into its component parts. Analysis also

refers to the process of examining information in order to make conclusions regarding cause and effect, interpreting motives, making inferences, or finding evidence to support statements/arguments.

5) **Evaluate** – being able to judge the value of information and/or sources of information based on personal values or opinions.
6) **Create** – the ability to creatively or uniquely apply prior knowledge and/or skills to produce new and original thoughts, ideas, processes, etc. At this level, students are involved in creating their own thoughts and ideas.

List of Action Words Related to Critical Thinking Skills

Figure 3 shows a list of action words that can be used when creating the expected student learning outcomes related to critical thinking skills in a course. These terms are organized according to the different levels of higher-order thinking skills contained in Anderson and Krathwohl's (2001) revised version of Bloom's taxonomy.

4. TIPS FOR DEVELOPING COURSE LEVEL EXPECTED LEARNING OUTCOMES STATEMENTS

- Limit the course-level expected learning outcomes to 5 - 10 statements for the entire course (more detailed outcomes can be developed for individual units, assignments, chapters, etc.).

- Focus on overarching or general knowledge and/or skills (rather than small or trivial details).

- Focus on knowledge and skills that are central to the course topic and/or discipline.
- Create statements that are student-centered rather than faculty-centered (e.g., "upon completion of this course students will be able to list the names of all Data Mining techniques " versus "one objective of this course is to teach the names of all Data Mining techniques").

- Focus on the learning that *results* from the course rather than describing activities or lessons in the course.

- Incorporate or reflect the institutional and departmental missions.

Incorporate various ways for students to show success (outlining, describing, modeling, depicting, etc.) rather than using a single statement such as "at the end of the course, students will know _____ " as the stem for each expected outcome statement.

5. SAMPLE COURSE LEARNING OUTCOMES

The following depict sample expected learning outcomes statements from the selected courses.

Linear Algebra & Calculus:
After completing this course the student must demonstrate the knowledge and ability to:

CAHSB02.01: Demonstrate knowledge of matrix calculation as an elegant and powerful mathematical language in connection with rank of a matrix.
CAHSB02.02: Determine rank by reducing the matrix to Echelon and Normal forms.
CAHSB02.03: Determine inverse of the matrix by Gauss Jordon Method.
CAHSB02.04: Interpret the Eigen values and Eigen vectors of matrix for a linear transformation and use properties of Eigen values
CAHSB02.05: Understand the concept of Eigen values in real-world problems of control field where they are pole of closed loop system.
CAHSB02.06: Apply the concept of Eigen values in real-world problems of mechanical systems where Eigen values are natural frequency and mode shape.
CAHSB02.07: Use the system of linear equations and matrix to determine the dependency and independency.
CAHSB02.08: Determine a modal matrix, and reducing a matrix to diagonal form.
CAHSB02.09: Evaluate inverse and powers of matrices by using Cayley-Hamilton theorem.
CAHSB02.10: Apply the Mean value theorems for the single variable functions.
CAHSB02.11: Find partial derivatives numerically and symbolically and use them to analyze and interpret the way a function varies.
CAHSB02.12: Find partial derivatives of and apply chain rule derivative techniques to multivariable functions.
CAHSB02.13: Understand the techniques of multidimensional change –of –variables to transform the coordinates by utilizing the Jacobian. Determine Jacobian for the coordinate transformation.
CAHSB02.14: Apply maxima and minima for functions of several variable's and Lagrange's method of multipliers.
CAHSB02.15: Find the complete solution of a non-homogeneous differential equation as a linear combination of the complementary function and a particular solution.
CAHSB02.16: Solving Second and higher order differential equations with constant coefficients.
CAHSB02.17: Apply the second order differential equations for real world problems of electrical circuits.
CAHSB02.18: Evaluate double integral and triple integrals of the given functions.
CAHSB02.19: Utilize the concept of change order of integration and change of variables to evaluate double integrals.
CAHSB02.20: Determine the area and volume of a given curve using double and triple integral.
CAHSB02.21: Analyze scalar and vector fields and compute the gradient, divergence and curl.
CAHSB02.22: Understand integration of vector function with given initial conditions.
CAHSB02.23: Evaluate line, surface and volume integral of vectors.
CAHSB02.25: Use Vector integral theorems to facilitate vector integration.

6. AN OVERVIEW OF ASSESSMENT

What is assessment?
According to Palomba and Banta (1999) assessment involves the systematic collection, review, and use of evidence or information related to student learning. Assessment helps faculty understand how well their students understand course topics/lessons. Assessment exercises are often anonymous. This anonymity allows students to respond freely, rather than trying to get the "right" answer or look good. Assessment exercises attempt to gauge students' understanding in order to see what areas need to be re-addressed in order to increase the students' learning.

In other words, assessment is the process of investigating (1) *what* students are learning and

(2) *how well* they are learning it in relation to the stated *expected learning outcomes* for the course. This process also involves providing feedback to the students about their learning and providing new learning opportunities/strategies to increase student learning.

For example, Dr. JVR initiates a class discussion on material from Chapter One and determines that most of the students are confused about Topic X. This class discussion served as a method for assessing student learning and helped determine the fact that student learning related to Topic X is somewhat lacking. Dr. JVR now has the opportunity to (1) inform the students that there is some confusion and (2) make adjustments to address this confusion (e.g., ask student to re-read Chapter One, re-lecture over Topic X, etc.). This assessment process helps increase students' learning.

What is the difference between "evaluation" and "assessment"?
Evaluation focuses on making a judgment about student work to be used in assigning marks that express the level of student performance. Evaluation is usually used in the process of *determining marks*. Evaluation typically occurs after student learning is assumed to have taken place (e.g., a final exam). Evaluation is part of the assessment process. Course assignments that are evaluated/graded (e.g., exams, papers, tutorials, etc.) are often seen as formal assessment techniques.

While evaluation is an important component of most classrooms, it does have some limitations. For example, if the class average on an exam is a 45%, is seems pretty clear that something went wrong along the way. When one has only evaluated the final learning product, it can be challenging to go back and discover what happened. It can also be difficult to address the situation or provide opportunities for students to learn from their mistakes. Yes, a curve on an exam can help address a low class average, but does it help the students learn? Engaging in informal assessment activities throughout the course can help avoid this situation.

What is involved in the assessment process?
1. Establishing *expected learning outcomes* for the course;
2. Systematically gathering, analyzing, and interpreting evidence *(through formal assessment activities such as exams or papers and informal assessment activities such as in-class discussions exercises)* to determine how well the students' learning matches:
    - Faculty expectations for what students will learn;
    - The stated expected learning outcomes for the course;
3. Faculty members should use this evidence/assessment of student learning to:
    - Provide questionnaire to students about their learning (or lack thereof);
    - Adjust their teaching methods and/or students' learning behaviors to ensure greater student learning (Maki, 2004);

The Best Practice in a Classroom Assessment and is an example of a method that can be used to assess learning outcomes. At the end of a class period or major topic, faculty ask students to anonymously write down what point(s) were the most unclear to them. After class, faculty members review these responses and then re-teach or re-address any confusing topics, thus increasing student learning (Angelo & Cross, 1993).

7. WRITING A COURSE PURPOSE

When planning a course and determining the Learning Outcomes for that course, it is important to examine the course's purpose within the context of the college, and/or the department/program. This process will assist faculty in determining the intent of the course as well as how the course fits into the curriculum. This will help identify the essential

knowledge, skills, etc. that should be incorporated into the course and the stated expected learning outcomes for the course. The course purpose section should clarify the course's standing within the programme *(e.g., is the course required or an elective?, does this class have a pre-requisite?, etc.)*. It should also describe the course's role in the departmental/programmatic curriculum by addressing the intent (importance, main contribution, intrinsic value, etc.) of the class.

Determine how the course fits into the departmental curriculum
Here are some questions to ask to help determine how a course fits in the departmental curriculum:

What role does the course play in the departmental/programmatic curriculum?

- Is this course required?
- Is this course an elective?
- Is this course required for some students and an elective for others?
- Does this class have a pre-requisite?
- Is this class a pre-requisite for another class in the department?
- Is this course part of IEEE / ACM / AICTE Model Curriculum?

How advanced is this course?

- Is this course an undergraduate or graduate course?
- Where does this course fall in students' degree plan - as an introductory course or an advanced course?
- Can I expect the students taking this course to know anything about the course topic?
- Are other faculty members counting on students who have taken this course to have mastered certain knowledge or skills?

When students leave this course, what do they need to know or be able to do?

- Is there specific knowledge that the students will need to know in the future?
- Are there certain practical or professional skills that students will need to apply in the future?
- Five years from now, what do you hope students will remember from this course?

What is it about this course that makes it unique or special?

- Why does the program or department offer this course?
- Why can't this course be "covered" as a sub-section of another course?
- What unique contributions to students' learning experience does this course make?
- What is the value of taking this course? How exactly does it enrich the program or department?

8. WRITING EXPECTED LEARNING OUTCOMES FOR A COURSE

The following pages should be of assistance in developing several broad, effectively stated expected learning outcomes for a course. When beginning to construct expected learning outcome statements, it is always good to think about the learners.

Please take a moment to think about the student learners in the course. Please consider the following questions:

- What are the most essential things the students need to know or be able to do at the end of this course?
- What knowledge and skills will they bring with them?

- What knowledge and skills should they learn from the course?

When you begin thinking about the expected learning outcomes for a course, it is a good idea to think broadly. Course-level expected learning outcomes do not need to focus on small details; rather, they address entire classes of theories, skill sets, topics, etc.

The "Course Description" contains the following contents: **(Annexure - A)**

- Course Overview
- Prerequisite(s)
- Marks Distribution
- Evaluation Scheme
- Course Objectives
- Course Outcomes
- How Program Outcomes are assessed
- How Program Specific Outcomes are assessed
- Syllabus
- List of Text Books / References / Websites / Journals / Others
- Course Plan
- Mapping course objectives leading to the achievement of the program outcomes and program specific outcomes
- Mapping course outcomes leading to the achievement of the program outcomes and program specific outcomes

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ANNEXURE - A: SAMPLE COURSE DESCRIPTION (As per NBA norms post June, 2015**)**

INSTITUTE OF AERONAUTICAL ENGINEERING
Dundigal, Hyderabad - 500 043

CIVIL ENGINEERING

COURSE DESCRIPTOR

Course Title	**LINEAR ALGEBRA AND CALCULUS**				
Course Code	**AHSB02**				
Programme	B.Tech				
Semester	I	CSE|ECE|AE|IT|EEE|CE|ME			
Course Type	Foundation				
Regulation	IARE - R18				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	-	-
Chief Coordinator	**Ms. L Indira, Assistant Professor**				
Course Faculty	**Dr. M Anita, Professor** **Dr. S Jagadha, Professor** **Mr. Ch Somashekar, Associate Professor** **Mr. V Subba Laxmi, Associate Professor** **Mr. J Suresh Goud, Assistant Professor** **Ms. P Srilatha, Assistant Professor** **Ms. C Rachana, Assistant Professor** **Ms. P Rajani, Assistant Professor** **Ms. B Praveena, Assistant Professor**				

I. COURSE OVERVIEW:

The course focuses on more advanced Engineering Mathematics topics which provide with the relevant mathematical tools required in the analysis of problems in engineering and scientific professions. The course includes types of Matrices and its applications, maxima and minima of functions of several variables, solutions of higher order ordinary differential equations, multiple integrals and vector calculus. The mathematical skills derived from this course form a necessary base to analytical and design concepts encountered in the program.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
-	-	-	-	-

III. MARKS DISTRIBUTION

Subject	SEE Examination	CIA Examination	Total Marks
Linear Algebra and Calculus	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✔	Chalk & Talk	✔	Quiz	✔	Assignments	✘	MOOCs
✔	LCD / PPT	✔	Seminars	✘	Mini Project	✔	Videos
✘	Open Ended Experiments						

V. EVALUATION METHODOLOGY

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into FIVE modules and each modules carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each module. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept.
50 %	To test the analytical skill of the concept OR to test the application skill of the concept.

Continuous Internal Assessment (CIA):
CIA is conducted for a total of 30 marks (Table 1), with 20 marks for Continuous Internal Examination (CIE), 05 marks for Quiz and 05 marks for Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Quiz	AAT	
CIA Marks	20	05	05	30

Continuous Internal Examination (CIE):
Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 20 marks of 2 hours duration consisting of five

descriptive type questions out of which four questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Quiz - Online Examination
Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are to be answered by choosing the correct answer from a given set of choices (commonly four). Such a question paper shall be useful in testing of knowledge, skills, application, analysis, evaluation and understanding of the students. Marks shall be awarded considering the average of two quiz examinations for every course.

Alternative Assessment Tool (AAT)
This AAT enables faculty to design own assessment patterns during the CIA. The AAT converts the classroom into an effective learning centre. The AAT may include tutorial hours/classes, seminars, assignments, term paper, open ended experiments, METE (Modeling and Experimental Tools in Engineering), five minutes video, MOOCs etc.

The AAT chosen for this course is given in section XI.

VI. COURSE OBJECTIVES (COs):

The course should enable the students to:	
I	Analyze and solve linear system of equations by using elementary transformations.
II	Determine the maxima and minima of functions of several variables by using partial differential coefficients..
III	Apply second and higher order linear differential equations to solve electrical circuits.
IV	Apply multiple integration to evaluate mass, area and volume of the plane.
V	Analyze gradient, divergence and curl to evaluate the integration over a vector field.

VII. COURSE LEARNING OUTCOMES (CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AHSB02.01	CLO 1	Demonstrate knowledge of matrix calculation as an elegant and powerful mathematical language in connection with rank of a matrix.	PO 1 PO 2	3
AHSB02.02	CLO 2	Determine rank by reducing the matrix to Echelon and Normal forms.	PO 1 PO 2	3
AHSB02.03	CLO 3	Determine inverse of the matrix by Gauss Jordon Method.	PO 1 PO 2	3
AHSB02.04	CLO 4	Interpret the Eigen values and Eigen vectors of matrix for a linear transformation and use properties of Eigen values	PO 1 PO 2	3
AHSB02.05	CLO 5	Understand the concept of Eigen values in real-world problems of control field where they are pole of closed loop system.	PO 1	3
AHSB02.06	CLO 6	Apply the concept of Eigen values in real-world problems of mechanical systems where Eigen values are natural frequency and mode shape.	PO2	2
AHSB02.07	CLO 7	Use the system of linear equations and matrix to determine the dependency and independency.	PO 2	2
AHSB02.08	CLO 8	Determine a modal matrix, and reducing a matrix to diagonal form.	PO 2	2
AHSB02.09	CLO 9	Evaluate inverse and powers of matrices by using Cayley-Hamilton theorem.	PO 2	2

AHSB02.10	CLO 10	Apply the Mean value theorems for the single variable functions.	PO 1 PO 2	3
AHSB02.11	CLO 11	Find partial derivatives numerically and symbolically and use them to analyze and interpret the way a function varies.	PO 1 PO 2	3
AHSB02.12	CLO 12	Find partial derivatives of and apply chain rule derivative techniques to multivariable functions.	PO 1 PO 2	3
AHSB02.13	CLO 13	Understand the techniques of multidimensional change –of –variables to transform the coordinates by utilizing the Jacobian. Determine Jacobian for the coordinate transformation.	PO 2	2
AHSB02.14	CLO 14	Apply maxima and minima for functions of several variable's and Lagrange's method of multipliers.	PO 1	3
AHSB02.15	CLO 15	Find the complete solution of a non-homogeneous differential equation as a linear combination of the complementary function and a particular solution.	PO 1	3
AHSB02.16	CLO 16	Solving Second and higher order differential equations with constant coefficients.	PO 1, PO 2	3
AHSB02.17	CLO 17	Apply the second order differential equations for real world problems of electrical circuits.	PO 1, PO 2	3
AHSB02.18	CLO 18	Evaluate double integral and triple integrals of the given functions.	PO 1, PO 2	3
AHSB02.19	CLO 19	Utilize the concept of change order of integration and change of variables to evaluate double integrals.	PO 1, PO 2	3
AHSB02.20	CLO 20	Determine the area and volume of a given curve using double and triple integral.	PO 1, PO 2	3
AHSB02.21	CLO 21	Analyze scalar and vector fields and compute the gradient, divergence and curl.	PO 1	3
AHSB02.22	CLO 22	Understand integration of vector function with given initial conditions.	PO1	2
AHSB02.23	CLO 23	Evaluate line, surface and volume integral of vectors.	PO 1	3
AHSB02.24	CLO 24	Use Vector integral theorems to facilitate vector integration.	PO 2	2

1 = Low **2 = Medium** **3 = High**

VIII. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	LCD / PPT
PO 2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences	2	Seminar

1 = Low **2 = Medium** **3 = High**

IX. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	**Engineering Knowledge**: Graduates shall demonstrate sound knowledge in analysis, design, laboratory investigations and construction aspects of civil engineering infrastructure, along with good foundation in mathematics, basic sciences and technical	1	LCD / PPT

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
	communication.		
PSO 2	**Broadness and Diversity:** Graduates will have a broad understanding of economical, environmental, societal, health and safety factors involved in infrastructural development, and shall demonstrate ability to function within multidisciplinary teams with competence in modern tool usage.	-	-
PSO 3	**Self-Learning and Service:** Graduates will be motivated for continuous self-learning in engineering practice and/or pursue research in advanced areas of civil engineering in order to offer engineering services to the society, ethically and responsibly.	-	-

1 = Low **2 = Medium** **3 = High**

X. MAPPING COURSE LEARNING OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 1	3	2											1		
CLO 2	3	2													
CLO 3	3	2													
CLO 4	3	2											1		
CLO 5	3														
CLO 6		2													
CLO 7		2													
CLO 8		2											1		
CLO 9		2											1		
CLO 10	3	2													
CLO 11	3	2											1		
CLO 12	3	2											1		
CLO 13		2													
CLO 14	3												1		
CLO 15	3														
CLO 16	3	2											1		
CLO 17	3	2											1		
CLO 18	3	2											1		
CLO 19	3	2											1		
CLO 20	3	2											1		
CLO 21	3														
CLO 22	3												1		
CLO 23	3														
CLO 24	2	2											1		

1 = Low **2 = Medium** **3 = High**

XI. ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PO 1	SEE Exams	PO 1	Assignments	-	Seminars	PO 2
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	-						

XII. ASSESSMENT METHODOLOGIES - INDIRECT

✔	Early Semester Feedback	✔	End Semester OBE Feed Back
✘	Assessment of Mini Projects by Experts		

XIII. SYLLABUS

Module-I	**THEORY OF MATRICES AND LINEAR TRANSFORMATIONS**	**Classes: 09**
Real matrices: Symmetric, skew-symmetric and orthogonal matrices; Complex matrices: Hermitian, Skew-Hermitian and unitary matrices; Elementary row and column transformations; Rank of a matrix: Echelon form and normal form; Inverse by Gauss-Jordan method; Cayley-Hamilton theorem: Statement, verification, finding inverse and powers of a matrix; Linear dependence and independence of vectors; Eigen values and Eigen vectors of a matrix and Properties (without proof); Diagonalization of matrix by linear transformation.		
Module-II	**FUNCTIONS OF SINGLE AND SEVERAL VARIABLES**	**Classes: 09**
Mean value theorems: Rolle's theorem, Lagrange's theorem, Cauchy's theorem-without proof; Functions of several variables: Partial differentiation, chain rule, total derivative, Euler's theorem, functional dependence, Jacobian, maxima and minima of functions of two variables without constraints and with constraints; Method of Lagrange multipliers.		
Module-III	**HIGHER ORDER LINEAR DIFFERENTIAL EQUATIONS AND THEIR APPLICATIONS**	**Classes: 09**
Linear differential equations of second and higher order with constant coefficients, non-homogeneous term of the type $f(x)=e^{ax}, \sin ax, \cos ax$ and $f(x)=x^n, e^{ax}v(x), x^n v(x)$; Method of variation of parameters; Applications to electrical circuits.		
Module-IV	**MULTIPLE INTEGRALS**	**Classes: 09**
Double and triple integrals; Change of order of integration. Transformation of coordinate system; Finding the area of a region using double integration and volume of a region using triple integration.		
Module-V	**VECTOR CALCULUS**	**Classes: 09**
Scalar and vector point functions; Definitions of Gradient, divergent and curl with examples; Solenoidal and irrotational vector point functions; Scalar potential function; Line integral, surface integral and volume integral; Vector integral theorems: Green's theorem in a plane, Stoke's theorem and Gauss divergence theorem without proofs.		
Text Books:		
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XIV. COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No	Topic/s to be covered	Course Learning Outcomes (CLOs)	Reference
1	Define types of matrices	CLO 1	T2:32.1 R1:4.1
2	Apply Elementary row and column transformation	CLO 2	T2:32.1 R1:4.2
3	Determine the Rank of a matrix, by Echelon form and Normal form	CLO 2	T2:32.1 R1:4.3
4	Apply Gauss Jordan method to find inverse	CLO 3	T2:32.1 R1:4.3
5	Apply Cayley-Hamilton theorem to find inverse of matrix	CLO 9	T2:32.5 R1:4.6
6	Distinguish Linear dependency and independence\y of vectors	CLO 7	T2:32.5 R1:4.6
7	Define and find Eigen values and Eigen vectors.	CLO 4	T2:32.4 R1:4.5
8	Define and apply the properties of Eigen values and Eigen vectors	CLO 4	T2:32.4 R1:4.5
9	Use diagonalisation to diagonalise a square matrix and find higher powers of a matrix	CLO 8	T2:32.7 R1:4.8
10	Apply the Rolle's theorem	CLO 10	T2:7.1 R1:7.4
11	Apply Lagrange's Mean Value Theorem	CLO 10	T2:7.1 R1:7.4
12	Apply Cauchy's Mean Value Theorem	CLO 10	T2:7.1 R1:7.4
13	Find partial derivatives and apply chain rule	CLO 11	T3-4.10
14	Find total derivatives and apply Euler's theorem	CLO 11	T3-4.71
15	Apply Jacobian transformation	CLO 13	T3-4.42
16	Determine maximum and minimum of a function of several variables	CLO 14	T2:7.1 R1:7.4
17	Determine maximum and minimum of a function of several variables	CLO 14	T2:7.1 R1:7.4
18	Use the Lagrange multiplier method to find extreme of functions with constraints	CLO 14	T2:15.5 R1:7.4
19	Determine complementary function for homogeneous higher order linear differential equations	CLO 16	T3-2.9 R1:2.1
20	Solving non-homogeneous higher order linear differential equations: methods of finding particular integral	CLO 17	T3-2.15 R1:2.8
21	Determine particular non-homogeneous term of the type $f(x) = e^{ax}$	CLO 16	T3-2.5 R1:2.8

Lecture No	Topic/s to be covered	Course Learning Outcomes (CLOs)	Reference
22	Determine particular non-homogeneous term of the type $f(x) = \sin ax, \cos ax$	CLO 16	T3-2.5 R1:2.8
23	Determine particular for non-homogeneous term of the type $f(x) = x^n$	CLO 16	T3-2.5 R1:2.8
24	Determine of finding particular for non-homogeneous term of the type $f(x) = e^{ax}v(x)$	CLO 16	T3-2.5 R1:2.8
25	Determine of finding particular integral for non-homogeneous term of the type $f(x) = x^n v(x)$	CLO 16	T3-2.5 R1:2.8
26	Solving second order linear differential equations using method of variation of parameters	CLO 16	T3-2.61 R1:2.10
27	Apply higher order differential method to electrical circuits	CLO 17	R1:2.12
28	Calculate double integrals of a function in Cartesian form	CLO19	T2:15.5 R1:7.5
29	Calculate double integrals of a function in polar form	CLO19	T2:16.5 R1:7.6
30	Use the Change of order of integrations Cartesian and polar form	CLO19	T2:16.5 R1:7.6
31	Use the Change of order of integrations Cartesian and polar form	CLO19	T2:16.5 R1:7.6
32	Use transformation of coordinate system to evaluate double integral	CLO19	T2:16.5 R1:7.6
33	Use transformation of coordinate system to evaluate double integral	CLO19	T2:16.5 R1:7.6
34	Calculate triple integrals in Cartesian form	CLO19	T2:11.1 R2:6.15
35	Apply double integration for finding the area	CLO20	T2:10.1 R1:16.1
36	Apply triple integration for finding the volume	CLO20	T2:10.1 R1:16.2
37	Define vector calculus and vector fields and their properties	CLO21	T2:10.3 R1:16.4
38	Determine Solenoidal and irrotational vector point function	CLO21	T2:11.3 R1:16.5
39	Determine Scalar potential function	CLO21	T2:11.3 R1:16.5
40	Calculate line integral along smooth path and find work done	CLO23	T2:11.3 R1:16.5
41	Calculate the surface area of field	CLO23	T2:11.3 R1:16.5
42	Calculate volume of field	CLO23	T2:11.3 R1:16.5
43	Use Green's theorem to evaluate line integrals along simple closed contours on the plane	CLO22	T2: 11.3 R1:16.11
44	Use Stokes' theorem to give a physical interpretation of the curl of a vector field	CLO22	T2: 11.3 R1:16.9
45	Use the divergence theorem to give a physical interpretation of the divergence of a vector field	CLO22	T2: 11.4 R1:16.18

XV. GAPS IN THE SYLLABUS - TO MEET INDUSTRY / PROFESSION REQUIREMENTS:

S NO	DESCRIPTION	PROPOSED ACTIONS	RELEVANCE WITH POS	RELEVANCE WITH PSOS
1	Matrices and its applications, applications of maxima and minima of functions of single and several variable.	Seminars	PO 1	PSO 1
2	Change of order of integration, geometrical interpretation of vector integral theorems and properties of gamma and Bessel differential equation.	Seminars / NPTEL	PO 4	PSO 1
3	Encourage students to solve real time applications and prepare towards competitive examinations.	NPTEL	PO 2	PSO 1

Prepared By: L Indira, Assistant Professor

HOD, CIVIL ENGINEERING