MLRITM

MARRI LAXMAN REDDY INSTITUTE OF TECHNOLOGY AND MANAGEMENT

Outcome Based Education (OBE) Manual

Department of Computer Science and Engineering

Regulation: UGR20

Contents

OVERVIEW

Outcome Based Education (OBE) is an educational model that forms the base of a quality education system. There is no single specified style of teaching or assessment in OBE. All educational activities carried out in OBE should help the students to achieve the set goals. The faculty may adapt the role of instructor, trainer, facilitator, and/or mentor, based on the outcomes targeted.

OBE enhances the traditional methods and focuses on what the Institute provides to students. It shows the success by making or demonstrating outcomes using statements "able to do" in favor of students. OBE provides clear standards for observable and measurable outcomes.

National Board of Accreditation (NBA) is an authorized body for the accreditation of higher education institutions in India. NBA is also a full member of the Washington Accord. NBA accredited programs and not the institutions.

Higher Education Institutions are classified into two categories by NBA

Tier – 1: Institutions consists of all IITs, NITs, Central Universities, State Universities and Autonomous Institutions. Tier –I institution can also claim the benefits as per the Washington Accord.

Tier-2: Institutions consists of affiliated colleges of universities.

What is Outcome Based Education (OBE)?

Institutions adopting OBE try to bring changes to the curriculum by dynamically adapting to the requirements of the different Stake holders like Students, Parents, Industry Personnel and Recruiters. OBE is all about feedback and outcomes.

Four levels of outcomes from OBE are:

1. Program Educational Objectives (PEOs)
2. Program Specific Outcomes(PSOs)
3. Program Outcomes (POs)
4. Course Outcomes (COs)

Why OBE?

1. International recognition and global employment opportunities.
2. More employable and innovative graduates with professional and soft skills, social responsibility and ethics.
3. Better visibility and reputation of the technical institution among stakeholders.
4. Improving the commitment and involvement of all the stakeholders.
5. Enabling graduates to excel in their profession and accomplish greater heights in their careers.

6. Preparing graduates for the leadership positions and challenging them and making them aware of the opportunities in the technology development.

Benefits of OBE

Clarity: The focus on outcome creates a clear expectation of what needs to be accomplished by the end of the course.
Flexibility: With a clear sense of what needs to be accomplished, instructors will be able to structure their lessons around the student's needs.
Comparison: OBE can be compared across the individual, class, batch, program and institute levels.
Involvement: Students are expected to do their own learning. Increased student's involvement allows them to feel responsible for their own learning, and they should learn more through this individual learning.

- Teaching will become a far more creative and innovative career
- Faculty members will no longer feel the pressure of having to be the "source of all knowledge".
- Faculty members shape the thinking and vision of students towards a course.

India, OBE and Accreditation:

From 13 June 2014, India has become the permanent signatory member of the Washington Ac- cord Implementation of OBE in higher technical education also started in India. The National Assessment and Accreditation Council (NAAC) and National Board of Accreditation (NBA) are the autonomous bodies for promoting global quality standards for technical education in India. NBA has started accrediting the programs running with OBE from 2013.

The National Board of Accreditation mandates establishing a culture of outcome-based education in institutions that offer Engineering, Pharmacy, and Management program Reports of outcome analysis help to find gaps and carryout continuous improvements in the education system of an Institute, which is very essential.

1. Vision, Mission, Quality Policy, Philosophy & Core Values

Vision

"To empower the students to be technologically adept, innovative, self-motivated and responsible global citizen possessing human values and contribute significantly towards high quality technical education by harmonizing innovation with sustainability."

Mission

M1: To offer high-quality education in the computing fields by providing an environment where the knowledge is gained and applied to participate in research, for both students and faculty.

M2: To develop the problem solving skills in the students to be ready to deal with cutting-edge technologies of the industry.

M3: To make the students and faculty excel in their professional fields by inculcating the communication skills, leadership skills, team building skills with the organization of various co-curricular and extra-curricular programmes.

M4: To provide the students with theoretical and applied knowledge, and adopt an education approach that promotes lifelong learning and ethical growth.

Quality Policy

Our policy is to nurture and build diligent and dedicated community of engineers providing a professional and unprejudiced environment, thus justifying the purpose of teaching and satisfying the stake holders.

A team of well qualified and experienced professionals ensure quality education with its practical application in all areas of the Institute.

Philosophy

The essence of learning lies in pursuing the truth that liberates one from the darkness of ignorance and Marri Laxman Reddy Institute of Technology and management firmly believes that education is for liberation.

Contained therein is the notion that engineering education includes all fields of science that plays a pivotal role in the development of world-wide community contributing to the

progress of civilization. This institute, adhering to the above understanding, is committed to the development of science and technology in congruence with the natural environs. It lays great emphasis on intensive research and education that blends professional skills and high moral standards with a sense of individuality and humanity. We thus promote ties with local communities and encourage transnational interactions in order to be socially accountable. This accelerates the process of transfiguring the students into complete human beings making the learning process relevant to life, instilling in them a sense of courtesy and responsibility.

Core Values

Excellence: All activities are conducted according to the highest international standards.
Integrity: Adheres to the principles of honesty, trustworthiness, reliability, transparency and accountability.
Inclusiveness: To show respect for ethics, cultural and religious diversity, and freedom of thought.
Social Responsibility: Promotes community engagement, environmental sustainability, and global citizenship. It also promotes awareness of, and support for, the needs and challenges of the local and global communities.
Innovation: Supports creative activities that approach challenges and issues from multiple perspectives in order to find solutions and advance knowledge.

2. Program Educational Objectives (PEOs)

Program Educational Objectives (PEOs) should be defined by the PAQIC after taking feedback from all stake holders. PEOs are a promise by the department to the aspiring students about what they will achieve once they join the program. PEO assessment is not made compulsory by NBA as it is quite difficult to measure in the Indian context. NBA assessors usually do not ask for PEO assessment. PEOs are about professional and career accomplishment after 4 to 5 years of graduation. PEOs can be written from different perspectives like Career, Technical Competency, and Behaviour. While writing the PEOs, do not use technical terms as it will be read by prospective students who want to join the program. Three to five PEOs are recommended.

Program Educational Objective - I: To induce strong foundation in mathematical and core concepts, which enable them to participate in research, in the field of computer science.

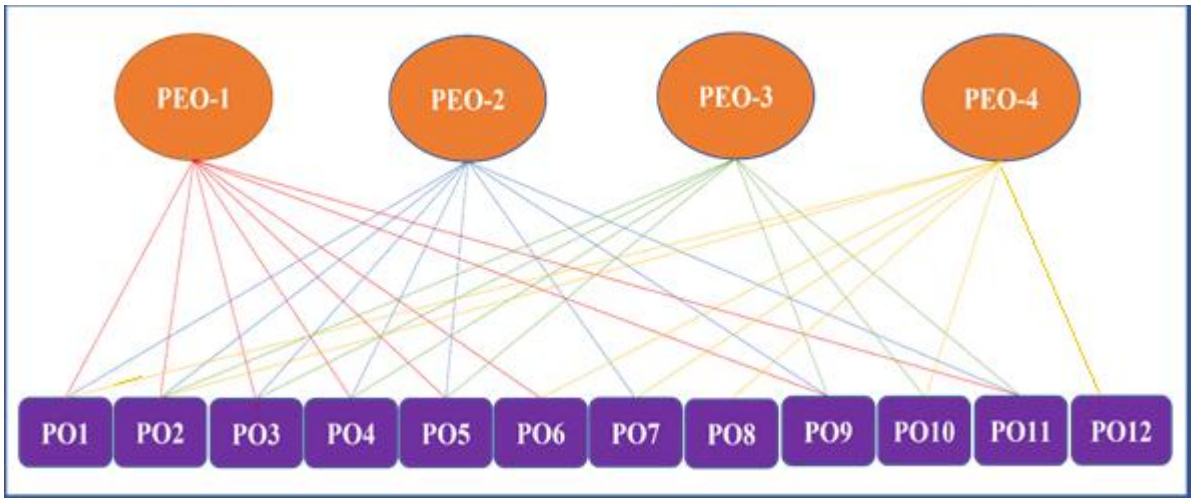
Program Educational Objective - II: To be able to become the part of application development and sustainability development by learning the computer programming methods, of the industry and related domains.

Program Educational Objective - III: To Gain the multidisciplinary knowledge by understanding the scope of association of computer science engineering discipline with other engineering disciplines.

Program Educational Objective - IV: To improve the soft skills which build the professional qualities, there by understanding the social responsibilities and ethical attitude.

2.1. Mapping of program educational objectives to program outcomes and program specific outcomes:

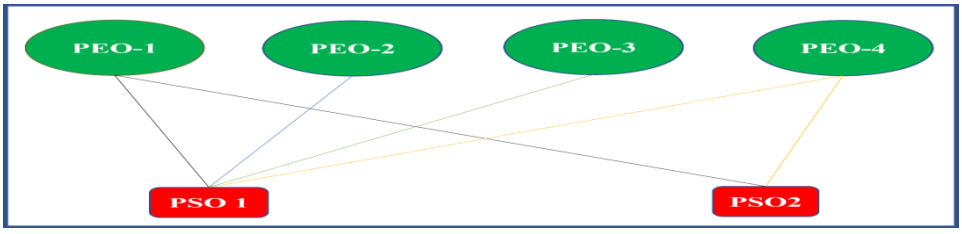
The following Figure 1 shows the correlation between the PEOs and the POs



PEO-I	PEO-II	PEO-III	PEO-IV
PO:1,2,3,4,5,6,9,11	**PO:**1,2,3,4,5,7,9,11	**PO:**2,3,4,5,9,10,11	**PO:1,2,**6,7,8,10,12

FIGURE1: Correlation between the PEOs and the Pos

The following Figure2 shows the correlation between the PEOs and the PSOs



PEO-I	PEO-II	PEO-III	PEO-IV
PSO:1,2	**PSO:**1,2	**PSO:**1,3	**PSO:**3

FIGURE2: Correlation between the PEOs and the PSOs

3. Program Out comes (POs)

A Program Learning Outcome is broad in scope and describes what a student should be able to do at the end of the program. POs are aligned with the graduate attributes specified in the **Washington Accord**. POs should be specific, measurable, and achievable.

The **NBA** has defined **12 POs**, which are common for all institutions in India.

In the syllabus book given to students, there should be a clear mention of **course objectives** and **course outcomes**, along with a **CO-PO course articulation matrix** for all the courses.

B. Tech (CSE) – PROGRAM OUTCOMES (PO's)	
A graduate of the Computer Science and Engineering Program will be demonstrated:	
PO1	**Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem Analysis:** Identify, formulate, review research literature, and analyse complex engineering problems, reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/Development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, as well as cultural, societal, and environmental considerations.
PO4	**Conduct Investigations of Complex Problems:** Use research-based knowledge and research methods, including the design of experiments, analysis and interpretation of data, and synthesis of information, to provide valid conclusions.
PO5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, andmodernengineeringandITtoolsincludingpredictionandmodelingtocomplex engineering activities with an understanding of the limitations.
PO6	**The Engineer and Society:** Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues, and the consequent responsibilities relevant to professional engineering practice.
PO7	**Environment and Sustainability:** Understand the impact of professional engineering solutions in societal and environmental contexts, and demonstrate knowledge of and the need for sustainable development.
PO8	**Ethics:** Apply ethical principles and commit to professional ethics, responsibilities, and norms of engineering practice.
PO9	**Individual and Teamwork:** Function effectively as an individual, as well as a member or leader in diverse teams and multidisciplinary settings.

PO10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and society at large. This includes the ability 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 engineering and management principles and apply these to one's own work as a member and leader in a team to manage projects 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.

4. Program Specific Outcomes (PSOs)

Program Specific Outcomes (PSOs) are statements that describe what the graduates of a specific engineering program should be able to do.

A list of PSOs written for the Department of Computer Science and Engineering is given below.

B. Tech (CSE) – PROGRAM SPECIFIC OUTCOMES (PSO's)	
A graduate of the Computer Science and Engineering Program will demonstrate:	
PSO1	Applications of Computing: Ability to use knowledge in various domains to provide solution to new ideas and innovations.
PSO2	Programming Skills: Identify required data structures, design suitable algorithms, develop and maintain software for real world problems.
PSO3	Entrepreneur and higher studies: Make use of computational and experimental tools for creating innovative career paths, to be an entrepreneur and desire for higher studies.

5. Relation between the Program Educational Objectives and the POs

Broad relationship between the program objectives and the program outcomes is given in the following Table below:

	PEO's→ ↓PO's	(1) Strong foundation in mathematics and CSE core concepts	(2) Application and sustainability development in industries	(3) Multi-disciplinary skills	(4) Social responsible and ethical attitude
PO1	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	3		
PO2	Identify, formulate, review research literature, and analyse complex engineering problems, reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3	2	1	1
PO3	Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, as well as cultural, societal, and environmental considerations.	2	3	2	1
PO4	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.	1	1	2	
PO5	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering activities with an understanding of the limitations.	2	2	3	

PO6	Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to professional engineering practice.	1			3
PO7	Understand the impact of professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of and need for sustainable development.		1	2	2
PO8	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.				3
PO9	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	2	1	3	
PO10	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.			2	1
PO11	Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work as a member and leader in a team, to manage projects in multidisciplinary environments.	2	2	1	
PO12	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.		1		

6. Relation between the Program Specific Outcomes and the Program Educational Objectives

PEO's→ ↓PSO's		(1) Strong foundation in mathematics and CSE core concepts	(2) Application and sustainability development in industries	(3) Multi-disciplinary skills	(4) Social responsible and ethical attitude
PSO1	Applications of Computing: Ability to use knowledge in various domains to provide solution to new ideas and innovations.	3	3	2	1
PSO2	Programming Skills: Identify required data structures, design suitable algorithms, develop and maintain software for real world problems.	2	3	2	
PSO3	Entrepreneur and higher studies: Make use of computational and experimental tools for creating innovative career paths, to be an entrepreneur and desire for higher studies.	3	3	2	1

Relationship between Program Specific Outcomes and Program Educational Objectives Key: 3 = High; 2 = Medium; 1= Low

Note:

- The assessment process of Pos and PSOs can be direct or indirect.

- The direct assessment will be done through interim assessment by conducting continuous internal exam and semester end exams.
- The indirect assessment on the other hand could be done through student's program exit questionnaire, alumni survey and employment survey.

7. Bloom's Taxonomy

Bloom's taxonomy is considered the global language for education. Bloom's Taxonomy is frequently used by teachers in writing course outcomes as it provides a ready-made structure and a list of action verbs. The stages ascend in complexity and what they demand of students.

First, students need to simply remember information provided to them—but reciting something doesn't demonstrate having learned it, only memorization. With understanding comes the ability to explain the ideas and concepts to others. The students are then challenged to apply the information and use it in new ways, helping to gain a deeper understanding of previously covered material and demonstrating it moving forward.

Questioning information is a vital part of learning, and both analysis and evaluation do just this. Analysing asks a student to examine the information in a new way, and evaluation demands the student appraise the material in a way that lets them defend or argue against it as they determine.

The final step in the revised taxonomy is creating, which entails developing a new product or point of view. How does this learned information impact your world? How can it be used to impact not just your education but the way you interact with your surroundings? By utilizing Bloom's Taxonomy, students are not going to forget the information as soon as the class ends rather, they retain and apply the information as they continue to grow as a student and in their careers, staying one step ahead of the competition.

7.1. Incorporating Critical Thinking Skills into Course Outcome 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 in Figure 3.

FIGURE3: Revised version of Bloom's taxonomy

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

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.

Understand – The ability to grasp the meaning of information (facts, definitions, concepts, etc.) that has been presented.

Apply – Being able to use previously learned information in different situations or in problem-solving.

Analyse – 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.

Evaluate – Being able to judge the value of information and/or sources of information based on personal values or opinions.

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.

7.3.List of Action Words Related to Critical Thinking Skills

Here is 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.
Here is the revised Bloom's document with action verbs, which we frequently refer to while writing COs for our courses.

The cognitive process dimensions - categories:

Lower Order of Thinking (LOT)			**Higher Order of Thinking (HOT)**		
Remember	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Interpreting Illustrating Classifying Summarizing Inferring (concluding) comparing explaining	Recognizing (identifying) Recalling (retrieving)	Executing Implementing	Differentiating Organizing Attributing	Checking (Coordinating) detecting, testing, monitoring) Critiquing (judging)	Planning Generating Producing (constructing)

The Knowledge Dimension			
Concrete Knowledge → Abstract knowledge			
Factual	**Conceptual**	**Procedural**	**Metacognitive**
• Knowledge of terminologies • Knowledge of specific details and elements.	• Knowledge of classifications and categories • Knowledge of principles and generalizations • Knowledge of theories, models and structures	• Knowledge of subject specific skills and algorithms • Knowledge of subject specific techniques and methods • Knowledge of criteria for determining when to use appropriate procedures	• Strategic Knowledge • Knowledge about cognitive task, including gap propriate contextual and conditional Knowledge • Self-Knowledge

Action Verbs for Course Out comes

Lower Order of Thinking (LOT)				Higher Order of Thinking (HOT)		
Definitions	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Bloom's Definition	Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding off acts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and Stating main ideas.	Solve problem s to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.	Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.	Compile information together in a different way by combining elements in a new pattern or proposing alternative solution.

Verbs	• Choose • Define • Find • How • Label • List • Match • Extend	• Classify • Compare • Contrast • Demonstrate • Explain • Illustrate • Infer • Interpret	• Apply • Build • Choose • Construct • Develop • Interview • Make use of • Model	• Analyze • Assume • Categorize • Classify • Compare • Discover • Dissect • Distinguish	• Agree • Appraise • Assess • Award • Choose • Criticize • Decide • Deduct • Importance	• Adapt • Build • Solve • Choose • Combine • Invent • Compile • Compose • Construct
Verbs	• Name • Omit • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why	• Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with	• Organize • Plan • Select • Solve • Utilize • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize • Identify	• Divide • Examine • Function • Inference • Inspect • List Motive • Simplify • Survey • Take part in • TestforTheme • Conclusion • Contrast	• Defend • Determine • Disprove • Estimate • Evaluate • Influence • Interpret • Judge • Justify Mark • Measure • Opinion • Perceive • Prioritize • Prove • Criteria • Criticize • Compare • Conclude	• Create • Design • Develop • Estimate • Formulate • Happen • Imagine • Improve • Makeup • Maximize • Minimize • Modify • Original • Originate • Plan • Predict • Propose • Solution

8. Guidelines for writing Course Outcome Statements:

Well-written course outcomes involve the following parts:

1. Action verb
2. Subject content
3. Level of achievement as per BTL
4. Modes of performing task (if applicable)

8.1. Course Outcomes (COs)

A Course Outcome is a formal statement of what students are expected to learn in a course. When creating Course Outcomes, remember that the outcomes should clearly state what students will do or produce to determine and/or demonstrate their learning. Course 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.

A well-formulated set of Course Outcomes will describe what a faculty member hopes to successfully accomplish in offering their particular course(s) to prospective students, or what specific skills, competencies, and knowledge the faculty member believes that students will have attained once the course is completed. The learning outcomes need to be concise descriptions of what learning is expected to take place by course completion.

8.2. Developing Course Outcomes

When creating course outcomes consider the following guidelines as you develop them either individually or as part of a multi-section group:

Limit the course outcomes to 5-6 statements for the entire course [more detailed outcomes can be developed for individual units, assignments, chapters, etc. if the instructor(s) wish (es)].

Focus on overarching knowledge and/or skills rather than small or trivial details.

Emphasize knowledge and skills that are central to the course topic and/or discipline.

Create statements that have a student focus rather than an instructor-centric approach. (Example:

Student-focused outcome: “Upon completion of this course, students will be able to list the names of the 28 states and 8 union territories.”

Instructor-centric objective (to avoid): “One objective of this course is to teach the names of the 28 states and 8 union territories.”).

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

Incorporate and/or reflect the institutional and departmental mission.

Include various ways for students to show success (e.g., 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.

When developing learning outcomes, here are the core questions to ask yourself:

- What do we want students in the course to learn?
- What do we want the students to be able to do?
- Are the outcomes observable, measurable, and able to be performed by the students?

Course outcome statements at the course level describe:

- What faculty members want students to know at the end of the course **AND**
- What faculty members want students to be able to do at the end of the course.

Course outcomes have three major characteristics:

- They specify an action by the students/learners that is **observable**.
- They specify an action by the students/learners that is **measurable**.
- 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. When stating expected learning outcomes, it is important to use **verbs that describe exactly what the student(s)/learner(s) will be able to do upon completion of the course**.

8.3. Relationship of Course Outcome to Program Outcome

Learning outcomesformula:

STUDENTS SHOULD BE ABLE TO + BEHAVIOR + RESULTING EVIDENCE

The Course Outcomes need to link to the Program Outcomes.

For example, you can use the following template to help you write an appropriate course level learning outcome.

"Upon completion of this course students will be able to (knowledge, concept, rule or skill you expect them to acquire) by (how will they apply the knowledge or skill/how will you assess the learning)."

8.4. Characteristics of Effective Course Outcomes

Well written course outcomes:

- Describe what you want your students to learning your course.
- A realigned with program goals and objectives.
- Tell how you will know an instructional goal has been achieved.
- Use action words that specify definite, observable behaviors.
- Arrases able through one or more indicators (papers, quizzes, projects, presentations, journals, portfolios, etc.)
- Are realistic and achievable.
- Use simple language.

8.5. Examples of Effective Course Outcomes

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

- Critically review the methodology of a research study published in a scholarly sociology journal.
- Design a web site using HTML and Java Script.
- Describe and present the contributions of women to American history.
- Recognize the works of major Re-naissance artists.
- Facilitating a group to achieve agreed – Up on gaols.
- Determine and apply the appropriate statistical procedures to analyze the results of simple experiments.
- Develop an individual learning plan for a child with a learning disability.
- Produce a strategic plan for a small manufacturing business.
- Analyseacharacter'smotivationandportraythatcharacterbeforeanaudienc e.
- Differentiate among five major approaches to literary analysis.
- List the major ethical issues one must consider when planning a human-subjects study.
- Locate and critically evaluate information on current political issues on the Web.
- List and describe the functions of the major components of the human nervous system.
- Correctly classify rock samples found in...
- Conduct a systems analysis of a group interaction.

- Demonstrate active listening skills when interviewing clients.
- Apply social psychological principles to suggest solutions to contemporary social problems.

A more detailed model for stating learning objectives requires at objectives have three parts: a condition, an observable behavior, and a standard.
The table below provides three examples.

S. No	Condition	Observable Behavior	Standard
1	Given a list of drugs	The student will be able to classify each item as amphetamine or barbiturate.	With at least70% accuracy
2	Immediately following a fifteen-minute discussion on a topic.	The student will be able to summarize in writing the major issues being discussed.	Mentioning at least three of the five major topics.
3	Given an algebraic equation with one unknown.	The student will be able to correctly solve a simple linear equation.	Within a period of five minutes.

The following examples describe a course outcome that is not measurable as written, an explanation for why the course outcome is not considered measurable, and a suggested edit that improves the course outcome

Original course out-come	Evaluation of language used in this course outcome	Improved course outcome
Explore in depth the literature on an aspect of teaching strategies.	Exploration is not a measurable activity, but the quality of the product of exploration would be measurable with a suitable rubric.	Upon completion of this course, the students will be able to: write a paper based on an in-depth exploration of the literature on an aspect of teaching strategies.

Examples those are TOO general and VERY HARD to measure...

- ...will appreciate the benefits of learning a foreign language.

- ...will be able to access resources at the Institute library.
- ...will develop problem-solving skills.
- ...will have more confidence in their knowledge of the subject matter.
- **Examples those are still general and HARD to measure...**
- ...will value knowing a second language as a communication tool.
- ...will develop and apply effective problem-solving skills that will enable one to adequately navigate through the proper resources within the institute library.
- ...will demonstrate the ability to resolve problems that occur in the field.
- ...will demonstrate critical thinking skills, such as problem-solving as it relates to social issues.
- **Examples those are SPECIFIC and relatively EASY to measure...**
- ...will be able to read and demonstrate good comprehension of text in areas of the student's interest or professional field.
- ...will demonstrate the ability to apply basic research methods in psychology, including research design, data analysis, and interpretation.
- ...will be able to identify environmental problems, evaluate problem-solving strategies, and develop science-based solutions.
- ...will demonstrate the ability to evaluate, integrate, and apply appropriate information from various sources to create cohesive, persuasive arguments, and to propose design concepts.
- **An Introspection - Examine Your Own Course Outcomes**

- If you have written statements of broad course goals, take a look at them. If you do not have a written list of course goals, reflect on your course and list the four to six most important student outcomes you want your course to produce.
- Look over your list and check the one most important student outcome. If you could only achieve one outcome, which one would it be?
- Look for your outcome on the list of key competencies or outcomes society is asking us to produce. Is it there? If not, is the reason a compelling one?
- Check each of your other "most important" outcomes against the list of outcomes. How many are on the list of key competencies?
- Take stock. What can you learn from this exercise about what you are trying to accomplish as a teacher? How clear and how important are your statements of outcomes for your use and for your students? Are they very specifically worded to avoid misunderstanding? Are they supporting important needs on the part of the students?

Write Your Course Outcomes!

One of the first steps you take in identifying the expected learning outcomes for your course is identifying the purpose of teaching the course. By clarifying and specifying the purpose of the

course, you will be able to discover the main topics or themes related to students' learning. Once discovered, these themes will help you to outline the expected learning outcomes for the course.

Ask yourself:

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

8.6. CO-PO Course Articulation Matrix (CAM)Mapping

A **Course Articulation Matrix** shows the educational relationship (Level of Learning achieved) between course outcomes and program outcomes for a course. This matrix strongly indicates whether the students are able to achieve the course learning objectives. The matrix can be used for any course and is a good way to evaluate a course syllabus.

Table 1 provides information about the action verbs used in the Program Outcomes (POs) and the nature of POs, stating whether the POs are technical or non-technical.

You need to understand the intention of each PO and the **Bloom's Taxonomy level** to which each of the section verbs in the POs correlates. Once you have understood the POs, you can write the **Course Outcomes (COs)** for a course and see to what extent each of those COs correlates with the POs.

TABLE 9: Process for mapping the values for CO-PO Matrix

Experiential learning	Experiential learning	Experiential learning	Experiential learning	Experiential learning
	PO1	Apply	L3	Bloom's L1 to L4 for theory courses. Bloom'sL1toL5forlaboratory courses. Bloom'sL1toL6for Project work, experiential learning
	PO2	Identify	L2	
		Formulate	L6	
		Review	L2	
	PO3	Design	L6	
		Develop	L3, L6	
	PO4	Analyze	L4	
		Interpret	L2, L3	
		Design	L6	

<table>
<tr><td rowspan="3">Technical</td><td rowspan="3">PO5</td><td>Create</td><td>L6</td><td rowspan="3"></td></tr>
<tr><td>Select</td><td>L1, L2, L6</td></tr>
<tr><td>Apply</td><td>L3</td></tr>
<tr><td rowspan="7">Non-Technical</td><td>PO6</td><td colspan="3" rowspan="7">Thumb Rule:
If Bloom’s L1 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign 1.
If Bloom’s L2 to L3 Action Verbs of a CO: Correlates with Any of PO6 to PO12, then assign 2.
If Bloom’s L4 to L6 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign3</td></tr>
<tr><td>PO7</td></tr>
<tr><td>PO8</td></tr>
<tr><td>PO9</td></tr>
<tr><td>PO10</td></tr>
<tr><td>PO11</td></tr>
<tr><td>PO12</td></tr>
</table>

At the end, the Program Outcomes (POs) can be calculated using various descriptors that you may define. The mapping of Course Outcomes (COs**)** towards a PO is evaluated using descriptors such as High, Medium, Low, etc.

Observations:

1. The first five Program Outcomes (POs) are purely technical in nature, while the other POs are non-technical.
2. For theory courses, while writing the Course Outcomes (COs), you need to restrict yourself between Bloom’s Level 1 to Level 4. However, if it is a programming course, restrict yourself between Bloom’s Level 1 to Level 3, but for other courses, you can go up to Bloom’s Level 4.
3. For laboratory courses, while composing COs, you need to restrict yourself between Bloom’s Level 1 to Level 5.
4. Only for mini-projects and main projects, you may extend up to Bloom’s Level 6 while composing COs.
5. For a given course, the course in-charge must involve all other professors who teach that course and ask them to come up with the CO-PO mapping. The course in-charge must take the average value of all these CO-PO mappings and finalize the values. Alternatively, the course in-charge can proceed with what the majority of faculty members prefer. Ensure that none of the professors handling the course discuss with each other while marking the CO-PO values.

6. If you want to match your COs with non-technical POs, correlate the action verbs used in the COs with the thumb rule given in the table and map the values. (This applies only for mapping COs to non-technical POs).

8.7. Tips for Assigning the values while mapping Cos to PO s.

1. Select action verbs for a Course Outcome (CO) from different Bloom's levels based on the importance of the particular CO for the given course.
2. Stick to a single action verb while composing COs, but you may use multiple action verbs if the need arises.
3. You need to justify the marking of values in the CO-PO articulation matrix. Use a combination of words found in the COs, POs, and your course syllabus for writing the justification. Restrict yourself to one or two lines.
4. Values for the CO-PO (technical POs in particular) matrix can be assigned by: (a) Judging the importance of the particular CO in relation to the PO s. If the CO matches strongly with a particular PO criterion, assign 3; if it matches moderately, assign 2; if the match is low, assign 1; otherwise, mark with a "-" symbol. (b) If an action verb used in a CO appears at multiple Bloom's levels, then you need to judge which Bloom's level is the best fit for that action verb.

8.8. Method for Articulation

1. Identify the key competencies of POs/PSOs for each CO and create a corresponding mapping table by assigning marks in the corresponding cell. One important observation is that the first five POs are purely technical in nature, while the other POs are non-technical.
2. Justify each CO-PO/PSO mapping with a justification statement and recognize the number of vital features mentioned in the justification statement that match the given Key Attributes for Assessing Program Outcomes. Use a combination of words found in the COs, POs/PSOs, and your course syllabus for writing the justification.
3. Create a table listing the number of key competencies for CO-PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
4. Create a table displaying the percentage of key competencies for CO-PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
5. Finally, prepare a Course Articulation Matrix (CO-PO/PSO Mapping) with COs and POs and COs and PSOs on a scale of 0 to 3, where:
    - 0 = No correlation (marked as "-")
    - 1 = Low/slight correlation
    - 2 = Medium/moderate correlation
    - 3 = Substantial/high correlation

The correlation is based on the following strategy:

Range (C%)	Correlation Level
0 ≤ C ≤ 5%	No correlation (0)
5% < C ≤ 40%	Low/Slight correlation (1)
40% < C < 60%	Moderate correlation (2)
60% ≤ C < 100%	Substantial/High correlation (3)

9. Key Competencies for Assessing Program Outcomes:

PO No.	NBA Statement / Vital Features	Key Components	No. of Key Components
PO1	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems (Engineering Knowledge).).	1. **Scientific Principles:** Application of scientific principles and methodologies. 2. **Mathematical Principles:** Utilization of mathematical concepts in problem-solving. 3. **Interdisciplinary Integration:** Integration of knowledge from various engineering disciplines. 4. **Engineering Specialization:** Application of specialized engineering knowledge in complex engineering problems.	**4**

PO 2.	Identify, formulate, review research literature, and analyze complex engineering problems, reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences (Problem Analysis).	1. **Identity:** Recognizing and defining complex engineering problems or opportunities. 2. **Formulate:** Structuring and abstracting the problem for systematic analysis. 3. **Review:** Examining research literature 4. **Analyze:** Investigating problems using data collection and relevant methodologies. 5. **First Principles:** Applying mathematical, natural, and engineering sciences in problem-solving. 6. **Substantiated Conclusions:** Ensuring accuracy and reliability through validation. 7. **Experimental Design:** Planning and conducting experiments for problem analysis. 8. **Solution Development:** Implementing and testing solutions through experimentation. 9. **Interpretation:** Evaluating results to draw meaningful engineering conclusions. 10. **Documentation:** Recording findings systematically for future reference and learning.	**10**

PO 3.	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/Development of Solutions).**	1. **Design:** Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. 2. **Solutions:** Understand customer and user needs while considering factors such as aesthetics. 3. **System Components:** Identify and manage cost drivers in engineering solutions. 4. **Processes:** Use creativity to develop innovative engineering solutions. 5. **Specified Needs:** Ensure fitness for purpose across production, operation, maintenance, and disposal. 6. **Public Health & Safety:** Manage the design process and evaluate outcomes for safety and risk assessment. 7. **Cultural Considerations:** Understand the commercial and economic context of engineering processes. 8. **Societal Considerations:** Apply management techniques to achieve engineering objectives in a broader context. 9. **Environmental Considerations:** Promote sustainable development through engineering activities. 10. **Appropriate Considerations:** Be aware of legal frameworks governing engineering activities, including personnel, health, safety, and environmental risks.	**10**

PO 4.	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 **(Conduct Investigations of Complex Problems).**	1. **Research-Based Knowledge:** Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively. 2. **Research Methods:** Develop essential laboratory and workshop skills to carry out experimental investigations and gather reliable data. 3. **Design of Experiments:** Address complex problems in various engineering contexts, including operations, management, and technology development. 4. **Analysis:** Leverage technical literature and reliable information sources. 5. **Interpretation of Data:** Follow appropriate codes of practice and industry standards when analyzing and interpreting experimental data. 6. **Synthesis:** Ensure high-quality results by integrating various data sources and considering quality control during engineering investigations. 7. **Valid Conclusions:** Draw valid conclusions by addressing technical uncertainties through sound reasoning and scientific principles. 8. **Engineering Principles:** Apply fundamental engineering principles to analyze and interpret key engineering processes and challenges. 9. **Modelling Techniques:** Use analytical and modeling techniques to identify, classify, and describe the performance of engineering systems and components. 10. **Quantitative Methods:** Employ analytical software and quantitative methods efficiently and accurately.	**10**

PO 5.	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 **(Modern Tool Usage).**	1. **Create:** Develop engineering solutions using modern tools across various disciplines. 2. **Select:** Identify appropriate prediction and modeling tools for diverse engineering applications. 3. **Apply:** Utilize IT tools in engineering analysis, design, and decision-making. 4. **Techniques:** Implement simulation tools in different engineering fields.	**4**
PO 6.	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 **(The Engineer and Society).**	1. **Contextual Knowledge:** Understand the commercial and economic context of engineering processes. 2. **Management Techniques:** Apply management strategies in engineering objectives within this context. 3. **Sustainable Development:** Promote sustainable development through engineering activities. 4. **Legal Awareness:** Recognize relevant legal requirements governing engineering practices, including health, safety, and environmental risks. **5. Professional Ethics:** Uphold high standards of professional and ethical conduct in engineering.	**5**

PO 7.	Understand the impact of the professional Engineering solutions in societal and Environmental contexts, and demonstrate the knowledge of, and need for sustainable development **(Environment and Sustainability).**	1. **Socio-Economic Impact:** Understand the socio-economic effects of engineering solutions on society. 2. **Political Impact:** Recognize the political implications and responsibilities of engineering solutions. 3. **Environmental Impact:** Assess the environmental consequences of engineering practices and solutions. 4. **Sustainability:** Demonstrate the importance of sustainable development in engineering solutions.	**4**
PO 8.	Apply ethical principles and commit to professional ethics and responsibilities and norms of the Engineering practice **(Ethics).**	1. **Ethical Judgement:** Make informed decisions based on ethical principles, using professional codes of ethics to guide actions and evaluate the ethical aspects of practice. 2. **Integrity:** Demonstrate a strong sense of trust and integrity, standing firm in one's values while acting responsibly and ethically. 3. **Fairness and Equity:** Ensure fair treatment and equity in all professional activities, valuing diversity and respecting others' perspectives. 4. **Professional Responsibility:** Adhere to the norms of engineering practice by committing to high ethical standards and demonstrating ethical behavior in all professional engagements.	**4**

PO9	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings **(Individual and Teamwork).**	1. **Independence:** Work effectively as an individual, taking ownership of tasks and driving progress independently. 2. **Maturity:** Demonstrate maturity by focusing on goal achievement, requiring minimal external motivation. 3. **Self-Direction:** Approach vaguely defined problems with systematic problem-solving skills to find solutions. 4. **Team Collaboration:** Engage in teamwork during various activities, including hands-on labs and multidisciplinary projects. 5. **Adaptability:** Participate in diverse team settings, adjusting to different roles and projects such as mini projects and design tasks. 6. **Project Management:** Understand and apply principles of teamwork and project management to effectively complete assignments and projects. 7. **Peer Evaluation:** Contribute to team dynamics by evaluating and reflecting on individual and group performance. 8. **Building Relationships:** Foster teamwork and lasting relationships, contributing to both academic success and post-graduation professional networks. 9. **Organizational Integration**: Collaborate with individuals across all levels of an organization, demonstrating adaptability and interpersonal skills. 10. **Effective Communication:** Develop strong relationships through positive interactions, showcasing an ability to get along with others and work cohesively in teams.	**10**

PO10	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 **(Communication).**	1. **Clarity:** Communicate complex engineering concepts clearly and concisely in written reports and design documentation. 2. **Grammar and Punctuation:** Ensure high standards of grammar and punctuation in written communication, maintaining professionalism and clarity. 3. **References:** Properly reference sources in written communication, ensuring accuracy and academic integrity. 4. **Speaking Style:** Deliver oral presentations effectively, with appropriate speaking style to engage the audience and convey technical information clearly. 5. **Subject Matter**: Demonstrate a deep understanding of the subject matter, clearly communicating complex ideas during oral discussions and presentations.	**5**

PO11	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 multi-disciplinary Environments (**Project Management and Finance).**	1. **Scope Definition:** Define the project scope clearly to ensure alignment with objectives and requirements. 2. **Critical Success Factors:** Identify and prioritize critical success factors necessary for project completion and success. 3. **Deliverables:** Ensure the timely delivery of project outputs, meeting the predefined objectives and quality standards. 4. **Work Breakdown Structure:** Develop and organize a structured breakdown of tasks and activities to achieve project goals. 5. **Scheduling:** Create and manage schedules to ensure tasks are completed on time and milestones are met. 6. **Budget Management:** Develop and manage project budgets, ensuring that resources are used efficiently and within financial constraints. 7. **Quality Assurance**: Apply quality control measures to ensure that project deliverables meet the required standards. 8. **Human Resources Planning:** Plan and allocate human resources effectively, ensuring the right skills and team dynamics. 9. **Stakeholder Management:** Identify and manage stakeholders, ensuring their needs and expectations are addressed throughout the project. 10. **Risk Management:** Develop a risk register and apply strategies to identify, assess, and mitigate project risks.	**10**

PO12	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 **(Life - Long Learning).**	1. **Professional Certificate:** Pursue professional, Academic, Global certifications. 2. **Advanced Education:** Begin and work towards advanced programs to further deepen knowledge. 3. **Continuous Learning:** Stay updated on industry trends and emerging technologies to remain relevant in the field. 4. **Skill Acquisition:** Learn at least 2–3 new significant skills annually to ensure continuous growth and development. 5. **Training Commitment:** Dedicate time for formal training for a standard duration of training each year. 6. **Personal Development:** Engage in ongoing self-improvement efforts to enhance both personal and professional growth. 7. **Adaptability:** Be adaptable to technological changes by actively pursuing new learning opportunities and challenges. 8. **Networking:** Build a network with industry peers and professionals to stay informed and grow knowledge through collaboration	**8**

10. Key Competencies for Assessing Program Specific Outcomes:

PSO	NBA statement/Vital features	No. of vital features
PSO1	Applications of Computing: Ability to use knowledge in various domains to provide solution to new ideas and innovations. 1. Base for project 2. Develop innovative Project 3. Inter domain knowledge integration to create innovative solutions 4. Collaborative efforts and diverse perspectives for new ideas and innovations	4
PSO2	Programming Skills: Identify required data structures, design suitable algorithms, develop and maintain software for real world problems. 1. Identify Data Structure 2. Design Algorithms 3. Implementation of projects using programming skill 4. Develop and maintain software for real world problems and modify overtime.	4
PSO3	Entrepreneur and higher studies: Make use of computational and experimental tools for creating innovative career paths, to be an entrepreneur and desire for higher studies. 1. Usage of existing tools 2. Computational base for higher studies 3. Developing Entrepreneurial Mindset 4. Use experimental tools for creating innovative career path	4

11. Program Outcomes and Program Specific outcomes Attained through course modules:

Courses offered in Computer Science and Engineering Curriculum (MLRS-R20) and POs/PSOs attained through course modules for I, II, III, IV, V, VI, VII and VIII semesters.

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
I B. Tech – I Semester																
2010001	Engineering Mathematics – I	✔	✔	✔	✔								✔	✔		
2010008	Engineering Chemistry	✔	✔				✔	✔								
2010501	Programming for Problem Solving	✔	✔	✔	✔								✔	✔	✔	
2010372	Engineering Workshop	✔		✔												
2010009	Communicative English						✔	✔	✔	✔	✔		✔		✔	✔
2010073	Engineering Chemistry Lab	✔	✔					✔						✔		
2010074	Communicative English Lab					✔	✔	✔	✔	✔	✔			✔		
2010571	Programming for Problem Solving Lab	✔	✔	✔	✔	✔							✔	✔	✔	
2010021	Environmental Science						✔	✔	✔	✔	✔					
I B. Tech- II Semester																
2020002	Engineering Mathematics - II	✔	✔	✔	✔									✔		
2020006	Applied Physics	✔	✔		✔			✔	✔					✔		
2020502	Data Structures	✔	✔	✔	✔								✔	✔	✔	
2020009	Engineering Drawing Practice	✔	✔	✔	✔									✔		
2020071	Applied Physics Lab	✔	✔	✔	✔		✔							✔		
2020572	Data Structures Lab	✔	✔	✔	✔	✔							✔	✔	✔	

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
II B.Tech- I Semester																
2030503	Database Management Systems	✔	✔	✔	✔	✔	✔						✔		✔	✔
2030010	Business Economics and Financial Analysis						✔	✔		✔	✔	✔		✔		
2030004	Probability And Statistics	✔	✔	✔	✔								✔	✔	✔	✔
2030504	Digital Logic Design	✔	✔	✔	✔	✔	✔	✔						✔		✔
2030505	Python Programming	✔	✔	✔	✔	✔				✔	✔			✔	✔	✔
2030573	Database Management Systems Lab	✔	✔	✔	✔	✔				✔	✔			✔	✔	✔
2030574	IT Workshop Lab	✔	✔	✔	✔	✔	✔			✔				✔		
2030575	Python Programming Lab	✔	✔	✔	✔	✔				✔	✔			✔	✔	✔
2030022	Gender Sensitization						✔	✔	✔	✔	✔					
II B.Tech- II Semester																
2040506	Discrete Mathematics	✔	✔	✔	✔	✔							✔	✔		
2040201	Basic Electrical Engineering	✔	✔	✔	✔											
2040507	Computer Organization &Microprocessors	✔	✔	✔	✔	✔				✔	✔			✔		✔
2040508	Design and Analysis of Algorithms	✔	✔	✔	✔	✔								✔	✔	✔
2040509	JAVA Programming	✔	✔	✔	✔	✔				✔	✔			✔	✔	
2040271	Basic Electrical Engineering Lab	✔	✔	✔	✔	✔								✔		
2040576	Design and Analysis of Algorithms through Java Lab	✔	✔	✔	✔	✔				✔	✔			✔	✔	
2040577	Computer Organization &Microprocessors Lab using MASAM	✔	✔	✔	✔	✔				✔	✔			✔		✔

2040023	Constitution of India						✔		✔	✔	✔					

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
III B.Tech- I Semester																
2050510	Operating Systems	✔	✔	✔	✔	✔	✔						✔	✔	✔	✔
2050511	Computer Networks	✔	✔	✔	✔	✔				✔	✔		✔	✔		✔
2050512	Formal Languages and Automata Theory	✔	✔	✔	✔					✔	✔			✔		
2050513	Software Engineering	✔	✔	✔	✔					✔	✔		✔	✔		✔
2050544	Information Retrieval Systems (Professional Elective I)	✔	✔	✔	✔	✔				✔	✔			✔		
2050578	Computer Networks Lab	✔	✔	✔	✔	✔				✔	✔		✔	✔		✔
2050579	Operating System Lab	✔	✔	✔	✔	✔	✔						✔	✔	✔	✔
2050580	Software Engineering Lab	✔	✔	✔	✔	✔				✔	✔			✔	✔	✔
2020024	Intellectual Property Rights						✔		✔	✔	✔		✔			
III B.Tech- II Semester																
2060514	Data Mining	✔	✔	✔	✔	✔	✔						✔		✔	✔
2060515	Compiler Design	✔	✔	✔	✔								✔	✔	✔	
2060516	Web Technologies	✔	✔	✔	✔	✔				✔	✔			✔	✔	✔
2060547	Cryptography and Network Security (Professional Elective II)	✔	✔	✔	✔	✔	✔			✔		✔	✔	✔		✔
2060101	Air and Noise Pollution (Open Elective I)						✔	✔	✔	✔	✔		✔	✔		
2060581	Data Mining Lab	✔	✔	✔	✔	✔	✔						✔		✔	✔
2060582	Web Technology Lab	✔	✔	✔	✔	✔	✔					✔		✔	✔	✔

2060075	Advanced English Communication Lab								✔	✔	✔	✔	✔			
2040025	Professional Ethics						✔	✔	✔	✔	✔					

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
IV B. Tech - I Semester																
2060514	Data Mining	✔	✔	✔	✔	✔	✔						✔		✔	✔
2060515	Compiler Design	✔	✔	✔	✔								✔	✔	✔	
2060516	Web Technologies	✔	✔	✔	✔	✔				✔	✔			✔	✔	✔
2060547	Cryptography and Network Security (Professional Elective II)	✔	✔	✔	✔	✔	✔			✔		✔	✔	✔		✔
2060101	Air and Noise Pollution (Open Elective I)						✔	✔	✔	✔	✔		✔	✔		
2060581	Data Mining Lab	✔	✔	✔	✔	✔	✔						✔		✔	✔
2060582	Web Technology Lab	✔	✔	✔	✔	✔	✔					✔		✔	✔	✔
2060075	Advanced English Communication Lab								✔	✔	✔	✔	✔			
2040025	Professional Ethics						✔	✔	✔	✔	✔					
2060514	Data Mining	✔	✔	✔	✔	✔	✔						✔		✔	✔
IVB. Tech- II Semester																
2080558	Deep Learning (Professional Elective V)	✔	✔			✔	✔		✔	✔			✔	✔		✔
2080563	Web Services (Professional Elective VI)	✔	✔	✔	✔		✔							✔		✔
2080103	Disaster Management (Open Elective III)	✔					✔	✔	✔	✔		✔				
2080587	Technical Seminar	✔	✔	✔	✔	✔				✔	✔			✔		✔
2080588	Project Stage-II	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔

12. Methods for measuring Learning Outcomes and Value Addition:

There are many different ways to assess student learning. In this section, we present the different types of assessment approaches available and the different frame works to interpret the results.

I. Continuous Internal Assessment (CIA).
II. Semester end examination (SEE)
III. Laboratory and project work
IV. Course exit survey
V. Program exit survey
VI. Alumni survey
VII. Employer survey
VIII. Course expert committee
IX. Department Advisory Board
X. Faculty meetings

The above assessment indicators are detailed below.

12.1. Continuous Internal Assessment (CIA)

Two Continuous Internal Examinations (CIEs) are conducted for all courses by the department. All students must participate in this evaluation process. These evaluations are critically reviewed by HOD and senior faculty and the essence is communicated to the faculty concerned to analyze, improve and practice so as to improve the performance of the student.

12.2. Semester End Examination (SEE)

The semester end examination is conducted for all the courses in the department. Before the Semester end examinations course reviews are conducted, feedback taken from students and remedial measures will be taken up such that the student gets benefited before going for end exams. The positive and negative comments made by the students about the course are recorded and submitted to the departmental academic council and to the principal for taking necessary actions to better the course for subsequent semesters.

12.3. Laboratory and Project Works

The laboratory work is continuously monitored and assessed to suit the present demands of the industry. Students are advised and guided to do project works giving solutions to research/ industrial problems to the extent possible by the capabilities and limitations of the student. The results of the assessment of the individual projects and laboratory work can easily be conflated in order to provide the students with periodic reviews of their overall progress and to produce terminal marks and grading.

12.4. Course Exit Surveys

Students are encouraged to fill-out a brief survey on the fulfillment of course objectives. The data is reviewed by the concerned course faculty and the results are kept open for the entire faculty. Based on this, alterations or changes to the course objectives are undertaken by thorough discussions in faculty and meetings.

12.5. Programme Exit Survey

The Program Exit Questionnaire is to be completed by all students leaving the institution. The questionnaire is designed to gather information from students regarding program educational objectives, overall program experiences, career choices, and any suggestions or comments for program improvement. The opinions expressed in the exit interview forms are reviewed by the Department Advisory Board (DAB) for potential implementation.

12.6. Alumni Survey

The survey gathers insights from former students of the department regarding their employment status, further education, perceptions of institutional emphasis, estimated gains in knowledge and skills, undergraduate involvement, and continued engagement with Marri Laxman Reddy Institute of Technology and Management. This survey is conducted every year, and the collected data is analyzed for continuous improvement.

12.7. Employer Survey

The main purpose of this employer questionnaire is to know employer's views about the skills they require of employees compared to the skills actually possessed by them. The purpose is also to identify gaps in technical and vocational skills, determine the need for required training practices to fill these gaps, and establish criteria for hiring new employees. These employer surveys are reviewed by the College Academic Council (CAC) to modify the present curriculum to suit the requirements of the employer.

12.8. Course Expert Committee

The course expert team is responsible in exercising the central domain of expertise in developing and renewing the curriculum and assessing its quality and effectiveness to the highest of professional standards. Inform the Academic Committee the 'day-to-day' matters as are relevant to the offered courses. This committee will consider the student and staff feedback on the efficient and effective development of the relevant courses. The committee also reviews the course full stack content developed by the respective course coordinator.

12.9. Department Advisory Board

The Departmental Advisory Board (DAB) plays an important role in the development of the department. The department-level Advisory Board is established to provide guidance and direction for the qualitative growth of the department. The board interacts and maintains liaison with key stakeholders.
The DAB will monitor the progress of the program and develop or recommend new or revised goals and objectives for the program. Additionally, the DAB will review and analyse the gaps between the curriculum and industry requirements, providing necessary feedback or advice to improve the curriculum

12.10. Faculty Meetings

The DAB meets bi-annually for every academic year to review the strategic planning and modification of PEOs. Faculty meetings are conducted at least once in a month for ensuring the implementation of PAQIC's suggestions and guidelines. All these proceedings are recorded and kept for the availability of all faculties.

12.11. Professional Societies

The importance of professional societies like CSI(Computer Society of India),ACM(Association for Computing Machinery),TASK(Telangana Academy of kill and Knowledge) search for knowledge. Student and faculty chapters of the above societies are constituted for a better technical and entrepreneurial environment. These professional societies promote excellence in instruction, research, public service and practice.

13. CO-Assessment processes and tools:

Course outcomes are evaluated based on two approaches namely direct and indirect assessment methods. The direct assessment methods are based on the Continuous Internal Assessment (CIA) and Semester End Examination (SEE) where as the indirect assessment methods are based on the course end survey and program exit survey provided by the students, Alumni and Employer.

The weightage in CO attainment of Direct and Indirect assessments are illustrated in Table.

Assessment Method	Assessment Tool	Weightage in CO attainment
Direct Assessment	Continuous Internal Assessment (CIE & Assignment)	80%
	Semester End Examination	
Indirect Assessment	Course End Survey	20%

13.1.Direct Assessment:

Direct assessment methods are based on the student's knowledge and performance in various assessments and examinations. These assessment methods provide evidence that a student has command over a specific course, content, or skill. Additionally, they demonstrate that the student's work exhibits specific qualities such as creativity, analysis, or synthesis.

The various direct assessment tools used to assess the impact of the delivery of course content is listed in the table.

- Continuous internal examination, semester end examinations, Assignment (includesassignment,5 minutes videos, seminars etc.) are used for CO calculation.
- The attainment values are calculated for individual courses and are formulated and summed for assessing the PO s.
- Performance in Assignment is indicative of the student's communication skills.

13.2. Indirect Assessment:

S. No	Courses	Components	Frequency	Max. Marks	Evidence
1	Core/ Elective	Continuous Internal Examination	Twice in a semester	25	Answer script
		Assignment	One Assignment per unit.	5	Assignment
		Semester End Examination	Once in a semester	70	Answer script
2	Laboratory	Observation and Result	Once in a week	05	Work sheets
		Record	Once in a week	05	Work sheets
		Viva	Once in a week	05	Work sheets
		Internal laboratory assessment	Twice in a semester	15	Answer script
		Semester End Examination	Once in a semester	70	Answer script
3	Project Work	Presentation	Twice in a semester	30	Presentation
		Semester End Examination	Once in a semester	70	Thesis report
4	Technical Seminar	Semester End Examination	Twice in a semester	100	Seminar report

Course End Survey-In this survey, questionnaires are prepared based on the level of understanding of the course and the questions are mapped to Course Outcomes. The tools and processes used in indirect assessment are shown in Table.

TABLE 15: Tools used in In-direct assessment

Tools	Process	Frequency
Course end survey	• Taken for every course at the end of the semester • Gives an overall view that helps to assess the extent of coverage/ compliance of COs • Helps the faculty to improve upon the various teaching methodologies	Once in a semester

Direct Tools: (Measurable in terms of marks and w.r.t.CO) Assessment done by faculty at department level.
Indirect Tools: (Non measurable (surveys) in terms of marks and w.r.t.CO) Assessment done at institute level.

14. PO/PSO-Assessment tools and Processes

The institute has the following methods for assessing the attainment of POs/PSOs.

1. Direct method
2. Indirect method

The attainment levels of course outcomes help in computing the PO/PSO based upon the mapping done.

TABLE 16: Attainment of PO / PSOs

	Assessment	Tools	Weight
POs/PSOs Attainment	Direct Assessment	CO attainment of courses	80%
	Indirect Assessment	Student exit survey	20%
		Alumni survey	
		Employer survey	

The CO values of both theory and laboratory courses, with appropriate weightage as per CO-PO mapping, as per the Program Articulation Matrix, are considered for the calculation of direct attainment of PO/PSOs.

PO Direct Attainment is calculated using the following rubric:

PO Direct Attainment = (Strength of CO-PO) * CO attainment / Sum of CO-PO strength.
The below figure represents the evaluation process of POs/PSOs attainment through course outcome attainment.

FIGURE 4: Evaluation process of POs / PSOs attainment

15. Course Descriptor:

The “Course Descriptor” provides general information regarding the topics and content addressed in the course. A sample course description is given in Annexure – A for reference.
The “Course Descriptor” contains the following contents:

- Course Overview
- Prerequisite(s)
- Marks Distribution
- Course Objectives
- Course Outcomes
- Content Delivery / Instructional Methodologies
- Syllabus
- List of Textbooks / References / Websites
- Evaluation Methodology
- Program Outcomes
- Program Specific Outcomes
- How Program Outcomes are Assessed
- How Program Specific Outcomes are Assessed
- Mapping of each CO with PO(s), PSO(s)
- Justification for CO–PO/PSO Mapping - Direct
- Total Count of Key Competencies for CO–PO/PSO Mapping
- Percentage of Key Competencies for CO–PO/PSO
- Course Articulation Matrix (PO/PSO Mapping)
- Assessment Methodology - Direct
- Assessment Methodology – Indirect
- Mapping with Sustainability development goals

DATA STRUCTURES

1	**Department**	COMPUTER SCIENCE AND ENGINEERING							
2	**Course Name**	DATA STRUCTURES							
3	**Course Code**	2020502							
4	**Year/Semester**	I/II							
5	**Regulation**	MLRS-R20							
6	**Structure of the course**	Theory				Practical			
		Lecture 3	Tutorials 0	Practical 0	Credit 3	L 0	T 0	P 0	C 0
7	**Type of course**	BS ×	HS ×	ES ✓	PC ×	PE ×	OE ×	CC ×	MC ×
8	**Course Offered**	Odd Semester	×	Even Semester ✓	×				
9	Total lecture, tutorial and practical hours for this course Offered (16 weeks of teaching per semester)								
	Lectures: 48 Hours	**Tutorials:** 0 hours		**Practical:** 0 hours					
10	**Course Coordinator**	Dr M Nagalakshmi							
11	**Date Approved by BOS**	10-12-2019							
12	**Course Webpage**	www.mlritm.ac.in/							
13	**Prerequisites/Co-requisites**	Level	Course Code	Semester	Prerequisites				
		UG	2010501	I	Programming For Problem Solving				

14. COURSE OVERVIEW

This course provides an in-depth study of data structures, their implementation, and applications in solving computational problems. It covers both fundamental and advanced data structures, analysing their efficiency and suitability for different scenarios.

15. COURSE OBJECTIVES

The students will try to learn:

- Exploring basic data structures such as linked list, stacks and queues
- Describes searching and sorting techniques.
- Introduces trees and graphs

16. COURSE OUTCOMES

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

CO No	Course Outcomes
CO 1	*Understand and apply various types of linear data structures such as singly linked lists, doubly linked lists, and circular linked lists to solve computational problems involving dynamic memory allocation and sequential data processing.*
CO 2	*Implement and analyze stack and queue operations using arrays and linked representations, and apply these structures to solve problems like infix-to-postfix conversion and postfix expression evaluation.*
CO 3	*Apply and compare different searching algorithms such as linear and binary search, and sorting algorithms like bubble sort, selection sort, insertion sort, merge sort, and quick sort to organize and retrieve data efficiently.*
CO 4	*Demonstrate usage of tree data structures including binary trees and binary search trees, and perform recursive and non-recursive traversals to support hierarchical data modeling and decision-making processes.*
CO 5	*Construct and explore graph representations, apply graph traversal algorithms such as BFS and DFS, and differentiate between trees and graphs for solving real-world problems involving network modeling and path finding.*

17. COURSE LEARNING OUTCOME (CLOs)

S No	Topic Name	CLO No	Course Learning Outcome (CLO)	Course Outcome	Bloom's Level
1	Introduction to Data Structures	CLO 1	**understanding, implementing, and analysing** various data structures and their applications.	CO 1	Understand
2	Linear list	CLO 2	Implement Linear List Operations	CO 1	Understand
3	Stacks	CLO 3	Understand the concept of stack	CO 1	Apply
4	stack applications	CLO 4	real world applications of stack	CO 2	Create
5	Queue	CLO 5	Understand the concept of queue.	CO 2	Understand
6	Searching	CLO 6	Implement Various Searching Algorithms	CO 2	Create
7	Searching applications.	CLO 7	Analyze the searching algorithms	CO 3	Apply
8	Sorting	CLO 8	Apply Sorting in Problem-Solving	CO 3	Apply
9	Sorting applications	CLO 9	Choose Appropriate Sorting Algorithm	CO 3	Apply
10	Trees	CLO 10	Evaluate the efficiency of Tree operations	CO 4	Understand
11	Recursive Traversals of Binary Tree	CLO 11	Apply recursive Traversal in problem -solving	CO 4	Create Design
12	Non Recursive Traversals of Binary Tree	CLO 12	Apply non recursive Traversal in problem -solving	CO 4	Understand
13	Trees and its applications	CLO 13	Use Trees in Algorithm Design	CO 5	Apply
14	Graphs	CLO 14	Evaluate Graph Performance and Complexity.	CO 5	Create
15	Graphs and its applications.	CLO 15	Use Graphs in Problem-Solving	CO 5	DESIGN

18. EMPLOYABILITY SKILLS

Example: Communication skills / Programming skills / Project based skills/ Mastering data structures enhances crucial employability skills, making you a strong candidate for roles in software development, data science,
Cyber-security and IT-related fields. Below are key skills gained: Ability to analyse complex problems and develop efficient solutions using appropriate data structures. Logical reasoning to break down problems and optimize solutions for time and space efficiency. Understanding time complexity (Big-O notation) to write optimized and scalable code. Designing efficient searching, sorting, and graph traversal algorithms for real-world applications.

19. CONTENT DELIVERY / INSTRUCTIONAL METHODOLOGIES

✓	 Power Point Presentation	✓	 Chalk & Talk	✓	 Assignments	×	 MOOC
✓	 ALP	✓	 Seminars	×	 Mini Project	×	 Videos

20. EVALUATION METHODOLOGY

The performance of a student in a course will be evaluated for 100 marks each, with 30 marks allotted for CIE (Continuous Internal Evaluation) and 70 marks for SEE (Semester End-Examination). In CIE, for theory subjects, during a semester, there shall be two mid-term examinations.

Each Mid-Term examination (30 Marks) consists of two parts

i) **Part – A** for 10 marks (Short Answer Types),
ii) **Part – B** for 20 marks (Descriptive answer Type) with a total duration of 1.5 hours as follows:

The average of two midterm examinations shall betaken as the final marks for mid term examinations.

The semester end examinations (SEE), will be conducted for 70 marks consisting of two parts viz.i) **Part-A** for 20 marks, ii) **Part-B** for 50 marks.

a. Part-A is a compulsory question which consists of ten sub-questions from all units carrying equal marks.

b. Part-B consists of five questions (numbered from 2 to 6) carrying 10 marks each. Each of these questions is from each unit and may contain sub-questions. For each question there will be an “either” “or” choice, which means that there will be two questions from each unit and the student should answer either of the two questions.

c. The duration of Semester End Examination is 3 hours.

Table 1: **Outline for Continues Internal Evaluation (CIE-I and CIE-II) and SEE**

Activities	CIE-I	CIE-II	Average of CIE	SEE	Total Marks
Continues Internal Evaluation (CIE)	25 Marks	25 Marks	30 Marks	70 Marks	Average of CIE + SEE
Assignment	5 Marks	5 Marks			
Total Marks	**30 Marks**	**30 Marks**	**30 Marks**	**70 Marks**	**100 Marks**

21. COURSE CONTENT - NUMBER OF MODULES

Module	Module Description	No. of Lectures
Module 1	Introduction to Data Structures, Linear list – singly linked list, doubly linked list, Circular linked list - operations and its applications	9
Module 2	Stacks- Introduction, Operations, array and linked representations of stacks, stack applications (Infix to postfix conversion and postfix evaluation), Queues-Introduction, operations, array and linked representations of queues and its applications	9
Module 3	Searching: Linear Search and Binary Search and its applications. Sorting: Bubble sort, Selection sort, Insertion sort, Merge sort, Quick sort and its applications	10
Module 4	Trees - Introduction, Types of trees, Binary tree, recursive and non-recursive Traversals of Binary Tree, Binary search tree- Operations and its applications.	10
Module 5	Graphs: Introduction, Types of graphs, Representation of graphs, Graph Traversal Methods, comparison between trees and graphs and its applications.	10

TEXT BOOKS:

1. Fundamentals of data structures in C, Horowitz, Sahani and Susan Anderson Freed, 2nd Edition, Universities Press.
2. Data structures using C, A.S. Tanenbaum, Y. Langsam, and M.J. Augenstein, PHI/Pearson education.

REFERENCES:

1. Data structures: A Pseudocode Approach with C, R.F. Gilberg And B.A. Forouzan, 2nd Edition, Cengage Learning.
2. Introduction to data structures in C, Ashok Kathman, 1st Edition, Pearson

22. ELECTRONIC RESOURCES

Resource Type	Title/Description	Link
Online Courses	Data structures: A Pseudocode Approach with C, R.F.Gilberg And B.A.Forouzan, 2nd Edition, Cengage Learning.	https://www.coursera.org/learn/data-structures
	2. Introduction to data structures in C, Ashok Kamthane, 1st Edition, PEARSON	https://www.coursera.org/learn/data-structures-in-c
	Data structures: A Pseudocode Approach with C, R.F.Gilberg And B.A.Forouzan, 2nd Edition, Cengage Learning.	https://www.edx.org/learn/data-structures
E-Books	"Introduction to data structures in C"	https://books.google.co.in/books?id=HHfP4M_SW6AC&printsec=copyright&redir_esc=y#v=onepage&q&f=false
	"Data structures using C"	https://books.google.co.in/books/about/Data_Structure_Using_C.html?id=ZgGzBt074e8C
Research Journals	ACM Transactions on Distributed Computing	ACM TDC
	ACM data structures	https://journals.stmjournals.com/ijdss/
YouTube Channels	MIT OpenCourseWare	MIT OpenCourseWare YouTube
	Computerphile	Computerphile YouTube

23. COURSE PLAN

S. No	Unit	Lecture no	Topic	Cos	Text book/ Chapter
1	**Unit - I**	LH1	Discussion on Outcome Based Education, CO, POs and PSOs		
2		LH2	Introduction to Data Structures	CO 1	T1
3		LH3	Single linked list	CO 1	T1
4		LH4	Double linked list	CO 1	T1
5		LH5	Circular linked list	CO 1	T1
6		LH6	Applications of linked list	CO 1	T1
7		LH7	Example programs on Linked list	CO 1	T1
8		LH8	Example programs on double linked list	CO 1	T1
9		LH9	ALP-1		
10	**Unit - II**	LH10	Operations	CO 2	T1
11		LH11	array representation of stacks	CO 2	T1

12		LH12	linked representation of stacks	CO 2	T1
13		LH13	Distributed Debugging	CO 2	T1
14		LH14	stack applications,	CO 2	T1
15		LH15	Queues-Introduction	CO 2	T1
16		LH16	array and linked representations of queues	CO 2	T1
17		LH17	queue applications.	CO 2	T1
18		LH18	ALP-2		
19	**Unit - III**	LH19	Linear Search	CO 3	T1
20		LH20	Binary Search	CO 3	T1
21		LH21	Applications on searching	CO 3	T1
22		LH22	Bubble sort	CO 3	T1
23		LH23	Selection sort	CO 3	T1
24		LH24	Insertion sort	CO 3	T1
25		LH25	Merge sort	CO 3	T1
26		LH26	Quick sort	CO 3	T1
27		LH27	Applications on sorting	CO 3	T1
28		LH28	ALP-3		
29	**Unit - IV**	LH29	Trees - Introduction	CO 4	T1
30		LH30	Types of trees	CO 4	T1
31		LH31	Binary tree	CO 4	T1
32		LH32	recursive and non- recursive	CO 4	T1
33		LH33	Binary search tree	CO 4	T1
34		LH34	Operation	CO 4	T1
35		LH35	applications.	CO 4	T1
36		LH36	Example programs on binary search and sorting	CO 4	T1
37		LH37	Example programs on binary tree	CO 4	T1
38		LH38	ALP-4		
39	**Unit - V**	LH39	Graphs: Introduction	CO 5	T1
40		LH40	Types of graphs	CO 5	T1
41		LH41	Representation of graphs	CO 5	T1
42		LH42	Graph Traversal Methods,	CO 5	T1
43		LH43	comparison between trees and graphs	CO 5	T1
44		LH44	applications	CO 5	T1
45		LH45	Example programs using graphs traverse	CO 5	T1
46		LH46	Realtime applications on graphs	CO 5	T1
47		LH47	Example programs on different types of graphs	CO 5	T1
48		LH48	ALP-5		

24. PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES

PO NO	NBA Statement / Vital Features		
	Graduate Attributes	**Program Outcomes**	**No. of key competencies**
PO1	Engineering knowledge	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	4
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.	10
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.	10
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.	10
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.	4
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	5
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.	4
PO8	Ethics	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.	4
PO9	Individual and team work	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	10
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.	5

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.	10
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	8

PO NO	**NBA Statement / Vital Features**	
	Program Specific Outcomes	**No. of key competencies**
PSO1	Applications of Computing: Ability to use knowledge in various domains to provide solution to new ideas and innovations.	4
PSO2	Programming Skills: Identify required data structures, design suitable algorithms, develop and maintain software for real world problems.	4
PSO3	Make use of computational and experimental knowledge for creating innovative career paths, to be an entrepreneur and desire for higher studies.	4

25. HOW PROGRAM OUTCOMES ARE ASSESSED

PO NO	**NBA Statement / Vital Features**			
	Graduate Attributes	**Program Outcomes**	**Strength**	**Proficiency Assessed by**
PO1	Engineering knowledge	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	CIE/PPT/ Objective / quiz /SEE/ Assignments
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.	3	CIE/PPT/ Objective / quiz /SEE/ Assignments
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.	2.8	CIE/PPT/ Objective / quiz /SEE/ Assignments
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.	2.6	CIE/PPT/ Objective / quiz /SEE/ Assignments

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.		CIE/PPT/ Objective / quiz /SEE/ Assignments
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		CIE/PPT/ Objective / quiz /SEE/ Assignments
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.		CIE/PPT/ Objective / quiz /SEE/ Assignments
PO8	Ethics	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.		CIE/PPT/ Objective / quiz /SEE/ Assignments
PO9	Individual and team work	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.		CIE/PPT/ Objective / quiz /SEE/ Assignments
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.		CIE/PPT/ Objective / quiz /SEE/ Assignments
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.		CIE/PPT/ Objective / quiz /SEE/ Assignments
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	2.4	CIE/PPT/ Objective / quiz /SEE/ Assignments

26. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED

PO NO	**NBA Statement / Vital Features**		
	Program Specific Outcomes	**Strength**	**Proficiency Assessed by**
PSO1	Applications of Computing: Ability to use knowledge in various domains to provide solution to new ideas and innovations.	2	CIE/PPT/ Objective / quiz /SEE/ Assignments
PSO2	Programming Skills: Identify required data structures, design suitable algorithms, develop and maintain software for real world problems.	3	CIE/PPT/ Objective / quiz /SEE/ Assignments
PSO3	Make use of computational and experimental knowledge for creating innovative career paths, to be an entrepreneur and desire for higher studies.	0	CIE/PPT/ Objective / quiz /SEE/ Assignments

3 = High; 2 = Medium; 1 = Low

27. MAPPING OF EACH CO WITH PO(s), PSO(s)

Course Outcomes (COs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
CO 1	Y	Y	Y	Y								Y	Y	Y	
CO 2	Y	Y	Y	Y								Y	Y	Y	
CO 3	Y	Y	Y	Y								Y		Y	
CO 4	Y	Y	Y	Y								Y		Y	
CO 5	Y	Y	Y	Y								Y	Y	Y	

28. JUSTIFICATIONS FOR CO – PO / PSO MAPPING - DIRECT:

Course Outcomes(COs)	POs / PSOs	Justification for mapping (Students will be able to)	No. of key competencies
CO 1	PO 1	1. **Scientific Principles:** Application of scientific principles and methodologies. 2. **Mathematical Principles:** Utilization of mathematical concepts in problem-solving. 3. **Interdisciplinary Integration:** Integration of knowledge from various engineering disciplines. 4. **Engineering Specialization:** Application of specialized engineering knowledge in complex engineering problems.	4
	PO2	1. **Identity:** Recognizing and defining complex engineering problems or opportunities. 2. **Formulate:** Structuring and abstracting the problem for systematic analysis. 3. **Review:** Examining research literature 4. **Analyze:** Investigating problems using data collection and relevant methodologies. 5. **First Principles:** Applying mathematical, natural, and engineering sciences in problem-solving. 6. **Substantiated Conclusions:** Ensuring accuracy and reliability	10

		through validation. 7. **Experimental Design:** Planning and conducting experiments for problem analysis. 8. **Solution Development:** Implementing and testing solutions through experimentation. 9. **Interpretation:** Evaluating results to draw meaningful engineering conclusions. **Documentation:** Recording findings systematically for future reference and learning.	
	PO3	1. **Design:** Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. 2. **Solutions:** Understand customer and user needs while considering factors such as aesthetics. 3. **System Components:** Identify and manage cost drivers in engineering solutions. 4. **Processes:** Use creativity to develop innovative engineering solutions. 5. **Specified Needs:** Ensure fitness for purpose across production, operation, maintenance, and disposal.	**5**
	PO4	1. **1. Research-Based Knowledge:** Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively. 2. **Research Methods:** Develop essential laboratory and workshop skills to carry out experimental investigations and gather reliable data. 3. **Design of Experiments:** Address complex problems in various engineering contexts, including operations, management, and technology development. 4. **Analysis:** Leverage technical literature and reliable information sources. 5. **Interpretation of Data:** Follow appropriate codes of practice and industry standards when analyzing and interpreting experimental data. 6. **Synthesis:** Ensure high-quality results by integrating various data sources and considering quality control during engineering investigations. 7. **Valid Conclusions:** Draw valid conclusions by addressing technical uncertainties through sound reasoning and scientific principles. 8. **Engineering Principles:** Apply fundamental engineering principles to analyze and interpret key engineering processes and challenges. 9. **Modelling Techniques:** Use analytical and modeling techniques to identify, classify, and describe the performance of engineering systems and components. **10. Quantitative Methods:** Employ analytical software and quantitative methods efficiently and accurately.	**10**
	PO12	1. **1. Professional Certificate:** Pursue professional, Academic, Global certifications. 2. **Advanced Education:** Begin and work towards advanced programs to further deepen knowledge. 3. **Continuous Learning:** Stay updated on industry trends and emerging technologies to remain relevant in the field.	**8**

		4. **Skill Acquisition:** Learn at least 2–3 new significant skills annually to ensure continuous growth and development. 5. **Training Commitment:** Dedicate time for formal training for a standard duration of training each year. 6. **Personal Development:** Engage in ongoing self-improvement efforts to enhance both personal and professional growth. 7. **Adaptability:** Be adaptable to technological changes by actively pursuing new learning opportunities and challenges. **8. Networking:** Build a network with industry peers and professionals to stay informed and grow knowledge through collaboration	
	PSO1	1. Base for project 2. Develop innovative Project	**2**
	PSO2	1. Identify Data Structure 2. Design Algorithms 3. Implementation of projects using programming skill 4. Develop and maintain software for real world problems and modify overtime.	**4**
CO 2	PO1	1. **Scientific Principles:** Application of scientific principles and methodologies. 2. **Mathematical Principles:** Utilization of mathematical concepts in problem-solving. 3. **Interdisciplinary Integration:** Integration of knowledge from various engineering disciplines. **4. Engineering Specialization:** Application of specialized engineering knowledge in complex engineering problems.	**4**
	PO2	5. **Identity:** Recognizing and defining complex engineering problems or opportunities. 6. **Formulate:** Structuring and abstracting the problem for systematic analysis. 7. **Review:** Examining research literature 8. **Analyze:** Investigating problems using data collection and relevant methodologies. 9. **First Principles:** Applying mathematical, natural, and engineering sciences in problem-solving. 10. **Substantiated Conclusions:** Ensuring accuracy and reliability through validation.	**7**
	PO3	**1. Design:** Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. **2.Solutions:** Understand customer and user needs while considering factors such as aesthetics. **3.System Components:** Identify and manage cost drivers in engineering solutions. **4.Processes:** Use creativity to develop innovative engineering solutions. **5.Specified Needs:** Ensure fitness for purpose across production, operation, maintenance, and disposal.	**5**

	PO4	**1.Research-Based Knowledge:** Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively. **2.Research Methods:** Develop essential laboratory and workshop skills to carry out experimental investigations and gather reliable data. **3.Analysis:** Leverage technical literature and reliable information sources. **4.Interpretation of Data:** Follow appropriate codes of practice and industry standards when analyzing and interpreting experimental data. **5.Synthesis:** Ensure high-quality results by integrating various data sources and considering quality control during engineering investigations.	**5**
	PO12	1. **Professional Certificate:** Pursue professional, Academic, Global certifications. 2. **Advanced Education:** Begin and work towards advanced programs to further deepen knowledge. 3. **Continuous Learning:** Stay updated on industry trends and emerging technologies to remain relevant in the field. 4. **Skill Acquisition:** Learn at least 2–3 new significant skills annually to ensure continuous growth and development.	**4**
	PSO1	1.Base for project 2.Develop innovative Project	**2**
	PSO2	1.Identify Data Structure 2.Design Algorithms 3.Implementation of projects using programming skill 4. Develop and maintain software for real world problems and modify overtime.	**4**
CO 3	PO 1	1. **Scientific Principles:** Application of scientific principles and methodologies. 2. **Mathematical Principles:** Utilization of mathematical concepts in problem-solving. 3. **Interdisciplinary Integration:** Integration of knowledge from various engineering disciplines. 4. **Engineering Specialization:** Application of specialized engineering knowledge in complex engineering problems.	**4**
	PO2	**1. Identity:** Recognizing and defining complex engineering problems or opportunities. **2.Formulate:** Structuring and abstracting the problem for systematic analysis. **3.Review:** Examining research literature **4.Analyze:** Investigating problems using data collection and relevant methodologies. **5.First Principles:** Applying mathematical, natural, and engineering sciences in problem-solving. **6.Substantiated Conclusions:** Ensuring accuracy and reliability	**8**

		through validation. **7.Experimental Design:** Planning and conducting experiments for problem analysis. **8.Solution Development:** Implementing and testing solutions through experimentation.	
	PO3	**1. Design:** Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. **2.Solutions:** Understand customer and user needs while considering factors such as aesthetics. **3. System Components:** Identify and manage cost drivers in engineering solutions. **4.Processes:** Use creativity to develop innovative engineering solutions. **5.Specified Needs:** Ensure fitness for purpose across production, operation, maintenance, and disposal. 6. **Public Health & Safety:** Manage the design process and evaluate outcomes for safety and risk assessment. 7. **Cultural Considerations:** Understand the commercial and economic context of engineering processes. 8. **Societal Considerations:** Apply management techniques to achieve engineering objectives in a broader context. 9. **Environmental Considerations:** Promote sustainable development through engineering activities. **10Appropriate Considerations:** Be aware of legal frameworks governing engineering activities, including personnel, health, safety, and environmental risks.	**10**
	PO4	1. **Research-Based Knowledge:** Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively. 2. **Research Methods:** Develop essential laboratory and workshop skills to carry out experimental investigations and gather reliable data. 3. **Design of Experiments:** Address complex problems in various engineering contexts, including operations, management, and technology development. 4. **Valid Conclusions:** Draw valid conclusions by addressing technical uncertainties through sound reasoning and scientific principles. 5. **Engineering Principles:** Apply fundamental engineering principles to analyze and interpret key engineering processes and challenges.	**5**
	PO12	1. **Professional Certificate:** Pursue professional, Academic, Global certifications. 2. **Advanced Education:** Begin and work towards advanced programs to further deepen knowledge. 3. **Continuous Learning:** Stay updated on industry trends and emerging technologies to remain relevant in the field. 4. **Skill Acquisition:** Learn at least 2–3 new significant skills annually to ensure continuous growth and development. 5. **Training Commitment:** Dedicate time for formal training for a	**5**

		standard duration of training each year.	
	PSO2	1.Identify Data Structure 2.Design Algorithms 3.Implementation of projects using programming skill 4.Develop and maintain software for real world problems and modify overtime.	**4**
CO 4	PO1	1. **Scientific Principles:** Application of scientific principles and methodologies. 2. **Mathematical Principles:** Utilization of mathematical concepts in problem-solving. 3. **Interdisciplinary Integration:** Integration of knowledge from various engineering disciplines. 4. **Engineering Specialization:** Application of specialized engineering knowledge in complex engineering problems.	**4**
	PO2	1. **Identity:** Recognizing and defining complex engineering problems or opportunities. 2. **Formulate:** Structuring and abstracting the problem for systematic analysis. 3. **Review:** Examining research literature 4. **Analyze:** Investigating problems using data collection and relevant methodologies. 5. **Experimental Design:** Planning and conducting experiments for problem analysis. 6. **Solution Development:** Implementing and testing solutions through experimentation. 7. **Solution Development:** Implementing and testing solutions through experimentation. 8. **Interpretation:** Evaluating results to draw meaningful engineering conclusions. 9. **Documentation:** Recording findings systematically for future reference and learning.	**9**
	PO3	1. **Design:** Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. 2. **Solutions:** Understand customer and user needs while considering factors such as aesthetics. 3. **System Components:** Identify and manage cost drivers in engineering solutions. 4. **Processes:** Use creativity to develop innovative engineering solutions. 5. **Specified Needs:** Ensure fitness for purpose across production, operation, maintenance, and disposal. 6. **Public Health & Safety:** Manage the design process and evaluate outcomes for safety and risk assessment. 7. **Cultural Considerations:** Understand the commercial and economic context of engineering processes. 8. **Societal Considerations:** Apply management techniques to achieve engineering objectives in a broader context. 9. **Environmental Considerations:** Promote sustainable development through engineering activities.	**9**

	PO4	1. 1. **Research-Based Knowledge:** Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively. 2. **Research Methods:** Develop essential laboratory and workshop skills to carry out experimental investigations and gather reliable data. 3. **Design of Experiments:** Address complex problems in various engineering contexts, including operations, management, and technology development. 4. **Analysis:** Leverage technical literature and reliable information sources. 5. **Interpretation of Data:** Follow appropriate codes of practice and industry standards when analyzing and interpreting experimental data. 6. **Synthesis:** Ensure high-quality results by integrating various data sources and considering quality control during engineering investigations. 7. **Valid Conclusions:** Draw valid conclusions by addressing technical uncertainties through sound reasoning and scientific principles. 8. **Engineering Principles:** Apply fundamental engineering principles to analyze and interpret key engineering processes and challenges. 9. **Modelling Techniques:** Use analytical and modeling techniques to identify, classify, and describe the performance of engineering systems and components. **10 Quantitative Methods:** Employ analytical software and quantitative methods efficiently and accurately.	**10**
	PO12	1. **Professional Certificate:** Pursue professional, Academic, Global certifications. 2. **Advanced Education:** Begin and work towards advanced programs to further deepen knowledge. 3. **Continuous Learning:** Stay updated on industry trends and emerging technologies to remain relevant in the field. 4. **Skill Acquisition:** Learn at least 2–3 new significant skills annually to ensure continuous growth and development.	**4**
	PSO2	1. Identify Data Structure 2.Design Algorithms 3.Implementation of projects using programming skill 4. Develop and maintain software for real world problems and modify overtime.	**4**
CO 5	PO1	1. **Scientific Principles:** Application of scientific principles and methodologies. 2. **Mathematical Principles:** Utilization of mathematical concepts in problem-solving. 3. **Interdisciplinary Integration:** Integration of knowledge from various engineering disciplines. **4. Engineering Specialization:** Application of specialized engineering knowledge in complex engineering problems.	**4**
	PO2	**1. Identity:** Recognizing and defining complex engineering problems or opportunities. **2.Formulate:** Structuring and abstracting the problem for	**10**

		systematic analysis. **3Review:** Examining research literature **4Analyze:** Investigating problems using data collection and relevant methodologies. **5.First Principles:** Applying mathematical, natural, and engineering sciences in problem-solving. **6.Substantiated Conclusions:** Ensuring accuracy and reliability through validation. **7.Experimental Design:** Planning and conducting experiments for problem analysis. **8.Solution Development:** Implementing and testing solutions through experimentation. **9.Interpretation:** Evaluating results to draw meaningful engineering conclusions. **10.Documentation:** Recording findings systematically for future reference and learning.	
	PO3	**1Design:** Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. **2Solutions:** Understand customer and user needs while considering factors such as aesthetics. **3.System Components:** Identify and manage cost drivers in engineering solutions. **4.Processes:** Use creativity to develop innovative engineering solutions. 5. **Specified Needs:** Ensure fitness for purpose across production, operation, maintenance, and disposal. 6. **Public Health & Safety:** Manage the design process and evaluate outcomes for safety and risk assessment. 7. **Cultural Considerations:** Understand the commercial and economic context of engineering processes. 8. **Societal Considerations:** Apply management techniques to achieve engineering objectives in a broader context.	**8**
	PO4	1. **Research-Based Knowledge:** Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively. 2. **Research Methods:** Develop essential laboratory and workshop skills to carry out experimental investigations and gather reliable data. 3. **Design of Experiments:** Address complex problems in various engineering contexts, including operations, management, and technology development. 4. **Analysis:** Leverage technical literature and reliable information sources. 5. **Interpretation of Data:** Follow appropriate codes of practice and industry standards when analyzing and interpreting	**10**

		experimental data. 6. **Synthesis:** Ensure high-quality results by integrating various data sources and considering quality control during engineering investigations. 7. **Valid Conclusions:** Draw valid conclusions by addressing technical uncertainties through sound reasoning and scientific principles. 8. **Engineering Principles:** Apply fundamental engineering principles to analyze and interpret key engineering processes and challenges. 9. **Modelling Techniques:** Use analytical and modeling techniques to identify, classify, and describe the performance of engineering systems and components. 10. **Quantitative Methods:** Employ analytical software and quantitative methods efficiently and accurately.	
	PO12	1. **Professional Certificate:** Pursue professional, Academic, Global certifications. 2. **Advanced Education:** Begin and work towards advanced programs to further deepen knowledge. 3. **Continuous Learning:** Stay updated on industry trends and emerging technologies to remain relevant in the field. 4. **Skill Acquisition:** Learn at least 2–3 new significant skills annually to ensure continuous growth and development. 5. **Training Commitment:** Dedicate time for formal training for a standard duration of training each year. 6. **Personal Development:** Engage in ongoing self-improvement efforts to enhance both personal and professional growth. 7. **Adaptability:** Be adaptable to technological changes by actively pursuing new learning opportunities and challenges. 8. **Networking:** Build a network with industry peers and professionals to stay informed and grow knowledge through collaboration	**8**
	PSO1	1.Inter domain knowledge integration to create innovative solutions 2.Collaborative efforts and diverse perspectives for new ideas and innovations	**2**
	PSO2	1.Identify Data Structure 2.Design Algorithms 3.Implementation of projects using programming skill 4.Develop and maintain software for real world problems and modify overtime.	**4**

29. TOTAL COUNT OF KEY COMPETENCIES FOR CO – (PO, PSO) MAPPING

Course Outcomes(COs)	Program Outcomes (POs) / Number of Vital Features												Program Specific Outcomes (PSOs) / Number of Vital Features		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
	4	**10**	**10**	**10**	**4**	**5**	**4**	**4**	**10**	**5**	**10**	**8**	**4**	**4**	**4**
CO 1	4	10	5	10								8	2	4	
CO 2	4	7	5	5								4	2	4	

CO 3	4	8	10	5								4		4	
CO 4	4	9	9	10								4		4	
CO 5	4	10	8	10								8	2	4	

30. PERCENTAGE OF KEY COMPETENCIES FOR CO – (PO/ PSO)

Course Outcomes(COs)	Program Outcomes (POs) / Number of Vital Features												Program Specific Outcomes (PSOs) / Number of Vital Features		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
	4	10	10	10	4	5	4	4	10	5	10	8	4	4	4
CO 1	100	100	50	100								100	50	100	
CO 2	100	70	50	50								50	50	100	
CO 3	100	80	100	50								50		100	
CO 4	100	90	90	100								50		100	
CO 5	100	100	80	100								100	50	100	

31. COURSE ARTICULATION MATRIX (PO – PSO MAPPING)

CO'S and PO'S, CO'S and PSO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

0 - 0≤ C≤ 5% – No correlation,

1- 5 <C≤ 40% – Low/ Slight

2 - 40 % <C < 60% –Moderate

3 - 60% ≤ C < 100% – Substantial /High

Course Outcomes(COs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
CO 1	3	3	3	3								3	2	3	
CO 2	3	3	2	2								2	2	3	
CO 3	3	3	3	2								2		3	
CO 4	3	3	3	3								2		3	
CO 5	3	3	3	3								3	2	3	
TOTAL	15	15	14	13								12	6	15	
AVERAGE	3	3	2.8	2.6								2.4	2	3	

32. ASSESSMENT METHODOLOGY DIRECT

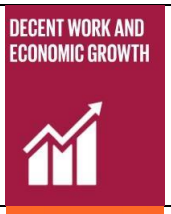
CIE Exams	✓	**SEE**	✓	**Seminars**	-
Objective / quiz	-	**Viva-Voce/PPT**	-	**MOOCS**	-
Assignments	✓	**Project**	-		

33. ASSESSMENT METHODOLOGY INDIRECT

✓	**Course End Survey (CES)**

34. RELEVANCE TO SUSTAINABILITY GOALS

✓	1		**Financial Inclusion**: Mobile banking and digital payment systems rely on distributed architectures to provide financial services to underserved populations. **Microfinance and Blockchain**: Secure, decentralized financial transactions support economic empowerment in low-income regions.
x	2		
x	3		
✓	4		**E-learning Platforms**: Cloud-based distributed systems support massive open online courses (MOOCs) and virtual classrooms. **Digital Libraries**: Distributed databases provide students worldwide with access to academic resources.
x	5		
✓	6		**Water Quality Monitoring**: IoT-based distributed sensors detect contamination in real-time. **Smart Water Management**: Distributed analytics optimize water distribution and waste treatment.
x	7		

x	8		
x	9		
x	10		
x	11		
x	12		
x	13		
x	14		
x	15		
x	16