IARE
INSTITUTE OF
AERONAUTICAL ENGINEERING

Outcome Based Education (OBE) Manual
UG20

Department of Computer Science and Engineering

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 favour of students. OBE provides clear standards for observable and measurable outcomes.

National Board of Accreditation (NBA) is an authorised body for the accreditation of higher education institutions in India. NBA is also a full member of the Washington Accord. NBA accredited programmes 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 - 1 institutions 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 stakeholders 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 Outcomes (POs)
3. Program Specific Outcomes (PSOs)
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 students' 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 Accord. 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 only 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, 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

1.1 Vision and Mission of the Institute

Institute Vision

To bring forth professionally competent and socially sensible engineers, capable of working across cultures meeting the global standards ethically.

Institute Mission

To provide students with an extensive and exceptional education that prepares them to excel in their profession, guided by dynamic intellectual community and be able to face the technically complex world with creative leadership qualities.

Further, be instrumental in emanating new knowledge through innovative research that emboldens entrepreneurship and economic development for the benefit of wide spread community.

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 Institute of Aeronautical Engineering 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.

1.2 Vision and Mission of the Department

Department Vision

The Vision of the department is to produce competent graduates suitable for industries and organizations at global level including research and development with Social responsibility.

Department Mission

To provide an open environment to foster professional and personal growth with a strong theoretical and practical background having an emphasis on hardware and software development making the graduates industry ready with social ethics.

Further the Department is to provide training and to partner with Global entities in education and research.

M1: To provide an **academic environment that will ensure high quality education, training and research.**

M2: To keep the students abreast of **latest research and innovations in science and technology.**

M3: To promote employability, entrepreneurship, **leadership qualities with ethics and research attitude**

2 Program Educational Objectives (PEOs)

Program Educational Objectives (PEOs) should be defined by the Head of the Department in consultation with the faculty members. PEOs are a promise by the department to the aspiring students about what they will achieve once they join the programme. PEO assessment is not made compulsory by NBA as it is quite difficult to measure in 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 the technical terms as it will be read by prospective students who wants to join the programme. Three to five PEOs are recommended.

Program Educational Objective – I: Success in Computer Science and Engineering:
Students will establish themselves as effective professionals by solving real problems through the use of computer science knowledge and with attention to team work, effective communication, critical thinking and problem solving skills.

Program Educational Objective – II: Industrial awareness and research:
Students will develop professional skills that prepare them for immediate employment and for lifelong learning in advanced areas of computer science and related fields.

Program Educational Objective – III: Successful employment and professional ethics:
Students will demonstrate their ability to adapt to a rapidly changing environment by having learned and applied new skills and new technologies.

Program Educational Objective – IV: Being a leader in professional and societal environment:
Students will be provided with an educational foundation that prepares them for excellence, leadership roles along diverse career paths with encouragement to professional ethics and active participation needed for a successful career. With a view to challenge ourselves and to nurture diverse capabilities for professional and intellectual growth for our students it is important for the department to define departmental objectives in generalized and broad format. Adherence to these objectives is proposed to be demonstrated through actions or achievements. The department of Computer Science and Engineering periodically reviews these objectives and as part of this review process, encourages comments from all interested parties including current students, alumni, prospective students, faculty, teaching assistants and members of related professional organizations, and colleagues from other educational institutions.

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, 7, 8, 9, 10, 11, 12	**PO:** 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12	**PO:** 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12	**PO:** 6, 7, 8, 9, 10, 11, 12

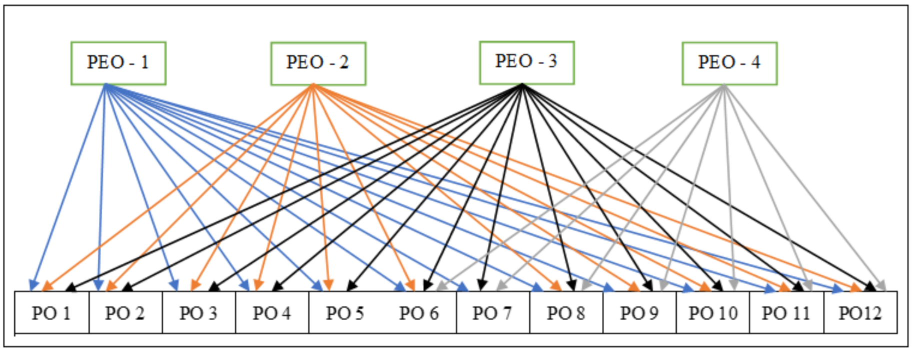


FIGURE 1: Correlation between the PEOs and the POs

The following Figure 2 shows the correlation between the PEOs and the PSOs

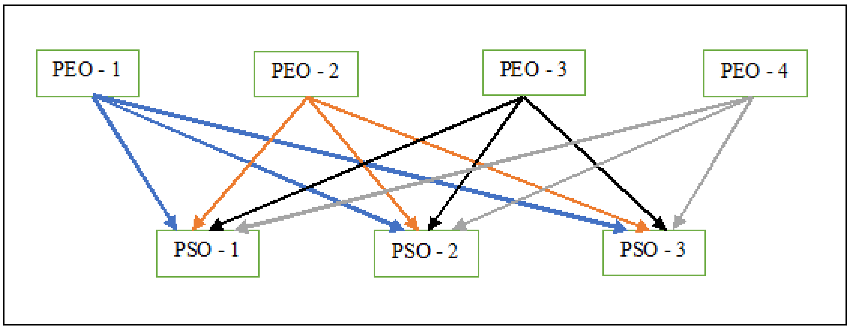


FIGURE 2: Correlation between the PEOs and the PSOs

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

3 Program Outcomes (POs)

A Program Learning Outcome is broad in scope and be able to do at the end of the programme. POs are to be in line with the graduate attributes as specified in the Washington Accord. POs are to be specific, measurable and achievable. NBA has defined 12 POs and you need not define those POs by yourself and it is common for all the institutions in India. In the syllabus book given to students, there should be clear mention of course objectives and course outcomes along with CO-PO course articulation matrix for all the courses.

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

PO10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

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	Understand, design and analyze computer programs in the areas related to Algorithms, System Software, Web design, Big data, Artificial Intelligence, Machine Learning and Networking.
PSO2	Focus on improving software reliability, network security or information retrieval systems.
PSO3	Make use of modern computer 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:

PEOs→ ↓POs	**(1) Success in Computer Science and Engineering Fields**	**(2) Industrial awareness and research**	**(3) Successful employment and professional ethics**	**(4) Being a leader in professional and societal environment**

PO1	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	3	3	-
PO2	Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3	3	2	-
PO3	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.	3	3	2	-
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.	3	3	2	-
PO5	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.	3	3	2	-

PO6	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.	2	3	3	3
PO7	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	2	2	3	3
PO8	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.	2	2	3	3
PO9	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings	2	3	3	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	3	3	3

PO11	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	3	3	3
PO12	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.	2	2	3	3

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

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

PEOs→ ↓ PSOs		**(1) Success in Computer Science and Engineering Fields**	**(2) Industrial awareness and research**	**(3) Successful employment and professional ethics**	**(4) Successful employment and professional ethics**
PSO1	Understand, design and analyze computer programs in the areas related to Algorithms, System Software, Web design, Big data, Artificial Intelligence, Machine Learning and Networking...	2	3	3	2
PSO2	Focus on improving software reliability, network security or information retrieval systems...	3	2	3	2

PSO3	Make use of modern computer tools for creating innovative career paths, to be an entrepreneur and desire for higher studies.	2	2	2	3

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 and 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 programme exit questionnaire, alumni survey and employment survey.

7 Blooms Taxonomy

Bloom's taxonomy is considered as the global language for education. Bloom's Taxonomy is frequently used by teachers in writing the course outcomes as it provides a readymade structure and 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 a developing 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.

FIGURE 3: Revised version of Bloom's taxonomy

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

1. **Remember** –recalling relevant terminology, specific facts, or different procedures related to information and/or course topics. At this level, a student can remember something, but may not really understand it.
2. **Understand** –the ability to grasp the meaning of information (facts, definitions, concepts, etc.) that has been presented.
3. **Apply** –being able to use previously learned information in different situations or in problem solving.
4. **Analyze** –the ability to break information down into its component parts. Analysis also refers to the process of examining information in order to make conclusions regarding cause and effect, interpreting motives, making inferences, or finding evidence to support statements/arguments.
5. **Evaluate** –being able to judge the value of information and/or sources of information based on personal values or opinions.
6. **Create** –the ability to creatively or uniquely apply prior knowledge and/or skills to produce new and original thoughts, ideas, processes, etc. At this level, students are involved in creating their own thoughts and ideas.

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**	**Analyse**	**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 appropriate contextual and conditional Knowledge • Self- Knowledge

Table 1: Action Verbs for Course Outcomes

	Lower Order of Thinking (LOT)			Higher Order of Thinking (HOT)		
Definitions	**Remember**	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
Bloom's Definition	Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas.	Solve problems 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

Table 1: Action Verbs for Course Outcomes

	Lower Order of Thinking (LOT)			Higher Order of Thinking (HOT)		
Definitions	**Remember**	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
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 • Test for Theme • 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 • Make up • 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 8-12 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
- Focus on 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 (basic e.g., "upon completion of this course students will be able to list the names of the 28 states and 8 union territories" versus "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 missions.
- Include various ways for students to show success (outlining, describing, modelling, 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 are they able to be performed by the students?

Course outcome statements on 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

The Course Outcomes need to link to the Program Outcomes.

Learning outcomes formula:

STUDENTS SHOULD BE ABLE TO + BEHAVIOR + RESULTING EVIDENCE

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 learn in your course.
- Are aligned with program goals and objectives.
- Tell how you will know an instructional goal has been achieved.
- Use action words that specify definite, observable behaviours.
- Are assessable 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 JavaScript.
- Describe and present the contributions of women to American history.
- Recognize the works of major Renaissance artists.
- Facilitate a group to achieve agreed-upon goals.
- 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.
- Analyse a character's motivation and portray that character before an audience.
- 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 that objectives have three parts: a condition, an observable behaviour, and a standard. The table below provides three examples.

S No	Condition	Observable Behaviour	Standard
1	Given a list of drugs	the student will be able to classify each item as amphetamine or barbiturate	with at least 70% 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 outcome	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 that 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 that 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 that 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

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.

The Table 1 gives information about the action verbs used in the POs and the nature of POs, stating whether the POs are technical or non-technical. You need to understand the intention of each POs and the Bloom's level to which each of these action verbs in the POs correlates to. Once you have understood the POs then you can write the COs for a course and see to what extent each of those CO's correlate with the POs.

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

<table>
<tr><th>Type</th><th>POs</th><th>Action Verb(s) in POs</th><th>Bloom's level(s) for POs</th><th>Bloom's level(s) for COs</th></tr>
<tr><td rowspan="13">Technical</td><td>PO1</td><td>Apply</td><td>L3</td><td rowspan="13">Bloom's L1 to L4 for theory courses.
Bloom's L1 to L5 for laboratory courses.
Bloom's L1 to L6 for project work, experiential learning</td></tr>
<tr><td rowspan="3">PO2</td><td>Identify</td><td>L2</td></tr>
<tr><td>Formulate</td><td>L6</td></tr>
<tr><td>Review</td><td>L2</td></tr>
<tr><td rowspan="2">PO3</td><td>Design</td><td>L6</td></tr>
<tr><td>Develop</td><td>L3, L6</td></tr>
<tr><td rowspan="3">PO4</td><td>Analyse</td><td>L4</td></tr>
<tr><td>Interpret</td><td>L2, L3</td></tr>
<tr><td>Design</td><td>L6</td></tr>
<tr><td rowspan="3">PO5</td><td>Create</td><td>L6</td></tr>
<tr><td>Select</td><td>L1, L2, L6</td></tr>
<tr><td>Apply</td><td>L3</td></tr>
<tr></tr>
<tr><td rowspan="6">Non-Technical</td><td>PO6</td><td colspan="3" rowspan="6">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</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>
</table>

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

Type	POs	Action Verb(s) in POs	Bloom's level(s) for POs	Bloom's level(s) for COs
	PO12	PO6 to PO12, then assign 3		

At the end, the POs can be calculated using various descriptors that you may define. The mapping of CO towards a PO is evaluated using descriptors such as High, Medium, Low etc. . .

Observations:

1. The first five POs are purely of technical in nature, while the other POs are non-technical.
2. For the theory courses, while writing the COs, you need to restrict yourself between Blooms Level 1 to Level 4. Again, if it is a programming course, restrict yourself between Blooms Level 1 to Level 3 but for the other courses, you can go up to Blooms Level 4.
3. For the laboratory courses, while composing COs, you need to restrict yourself between Blooms Level 1 to Level 5.
4. Only for Mini-project and Main project, you may extend up to Blooms Level 6 while composing COs.
5. For a given course, the course in-charge has to involve all the other Professors who teach that course and ask them to come up with the CO-PO mapping. The course in-charge has to take the average value of all of these CO-PO mappings and finalize the values or the course in-charge can go with what the majority of the faculty members prefer for. Ensure that none of the Professors who are handling the particular course discuss with each other while marking the CO-PO values.
6. If you want to match your COs with non-technical POs, then correlate the action verbs used in the course COs with the thumb rule given in the table and map the values. (Applies only for mapping COs to non-technical POs).

8.7 Tips for Assigning the values while mapping COs to POs.

1. Select action verbs for a CO from different Bloom's levels based on the importance of the particular CO for the given course.
2. Stick on to single action verbs while composing COs but you may go for multiple action verbs if the need arises.
3. You need to justify for marking of the values in 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 to CO-PO (technical POs in particular) matrix can be assigned by
   (a) Judging the importance of the particular CO in relation to the POs. If the CO matches strongly with a particular PO criterion then assign 3, if it matches moderately then assign 2 or if the match is low then assign 1 else mark with " - " symbol.
   (b) If an action verb used in a CO is repeated 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 to each CO and make a corresponding mapping table with assigning ✓mark at the corresponding cell. One observation to be noted is that the first five POs are purely of 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 are matching with 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. Make a table with number of key competencies for CO – PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
4. Make a table with percentage of key competencies for CO – PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
5. Finally, Course Articulation Matrix (CO - PO / PSO Mapping) is prepared with COs and POs and COs and PSOs on the scale of 0 to 3, 0 being no correlation (marked with " - "), 1 being the low/slight correlation, 2 being medium/moderate correlation and 3 being substantial/high correlation based on the following strategy

$$0–0 \leqq C \leqq 5\%$$ - No correlation.

$1-5 < C \leqq 40\%$ - Low / Slight. $2-40\% < C < 60\%$ - Moderate $3-60\% \leqq C < 100\%$ - Substantial / High

9 Key Competencies for Assessing Program Outcomes:

PO	NBA statement / Vital features	No. of vital features
PO1	**Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems (Engineering Knowledge).Knowledge, understanding and application of** 1. Scientific principles and methodology 2. Mathematical principles 3. Own and / or other engineering disciplines to integrate / support study of their own engineering discipline	3

PO	NBA statement / Vital features	No. of vital features
PO2	**Identify, formulate, review research literature, and analyse complex Engineering problems reaching substantiated conclusions using first principles of mathematics natural sciences, and Engineering sciences (Problem Analysis).** 1. Problem or opportunity identification 2. Problem statement and system definition 3. Problem formulation and abstraction 4. Information and data collection 5. Model translation 6. Validation 7. Experimental design 8. Solution development or experimentation / Implementation 9. Interpretation of results 10. Documentation	3
PO3	**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. Investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues 2. Understand customer and user needs and the importance of considerations such as aesthetics 3. Identify and manage cost drivers 4. Use creativity to establish innovative solutions 5. Ensure fitness for purpose for all aspects of the problem including production, operation, maintenance and disposal 6. Manage the design process and evaluate outcomes 7. Knowledge and understanding of commercial and economic context of engineering processes 8. Knowledge of management techniques which may be used to achieve engineering objectives within that context 9. Understanding of the requirement for engineering activities to promote sustainable development 10. Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk issues	10

PO	NBA statement / Vital features	No. of vital features
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 (Conduct Investigations of Complex Problems).** 1. Knowledge of characteristics of particular materials, equipment, processes, or product 2. Workshop and laboratory skills 3. Understanding of contexts in which engineering knowledge can be applied (example, operations and management, technology development, etc.) 4. Understanding use of technical literature and other information sources Awareness of nature of intellectual property and contractual issues 5. Understanding of appropriate codes of practice and industry standards 6. Awareness of quality issues 7. Ability to work with technical uncertainty. 8. Understanding of engineering principles and the ability to apply them to analyse key engineering processes 9. Ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modeling techniques 10. Ability to apply quantitative methods and computer software relevant to their engineering discipline, in order to solve engineering problems 11. Understanding of and ability to apply a systems approach to engineering problems.	11
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 (Modern Tool Usage).** 1. Computer software / simulation packages / diagnostic equipment / technical library resources / literature search tools.	1

PO	NBA statement / Vital features	No. of vital features
PO6	**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. Knowledge and understanding of commercial and economic context of engineering processes 2. Knowledge of management techniques which may be used to achieve engineering objectives within that context 3. Understanding of the requirement for engineering activities to promote sustainable development 4. Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk (including environmental risk) issues 5. Understanding of the need for a high level of professional and ethical conduct in engineering	5
PO7	**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). Impact of the professional Engineering solutions (Not technical)** 1. Socio economic 2. Political and 3. Environmental	3
PO8	**Apply ethical principles and commit to professional ethics and responsibilities and norms of the Engineering practice (Ethics)**. 1. Comprises four components:ability to make informed ethical choices, knowledge of professional codes of ethics, evaluates the ethical dimensions of professional practice, and demonstrates ethical behavior. 2. Stood up for what they believed in 3. High degree of trust and integrity	3

PO	NBA statement / Vital features	No. of vital features
PO9	**Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings (Individual and Teamwork).** 1. Independence 2. Maturity – requiring only the achievement of goals to drive their performance 3. Self-direction (take a vaguely defined problem and systematically work to resolution) 4. Teams are used during the classroom periods, in the hands-on labs, and in the design projects. 5. Some teams change for eight-week industry oriented Mini-Project, and for the seventeen - week design project. 6. Instruction on effective teamwork and project management is provided along with an appropriate textbook for reference. 7. Teamwork is important not only for helping the students know their classmates but also in completing assignments. 8. Students also are responsible for evaluating each other's performance, which is then reflected in the final grade. 9. Ability to work with all levels of people in an organization 10. Ability to get along with others 11. Demonstrated ability to work well with a team 12. Subjective evidence from senior students shows that the friendships and teamwork extend into the Junior years, and for some of those students, the friendships continue into the workplace after graduation.	12
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). "Students should demonstrate the ability to communicate effectively in writing / Orally."** 1. Clarity (Writing) 2. Grammar/Punctuation (Writing) 3. References (Writing) 4. Speaking Style (Oral) 5. Subject Matter (Oral)	5

PO	NBA statement / Vital features	No. of vital features
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 multidisciplinary Environ ments (Project Management and Finance).** 1. Scope Statement 2. Critical Success Factors 3. Deliverables 4. Work Breakdown Structure 5. Schedule 6. Budget 7. Quality 8. Human Resources Plan 9. Stakeholder List 10. Communication 11. Risk Register 12. Procurement Plan	12
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. Project management professional certification / MBA 2. Begin work on advanced degree 3. Keeping current in CSE and advanced engineering concepts 4. Personal continuing education efforts 5. Ongoing learning – stays up with industry trends/ new technology 6. Continued personal development 7. Have learned at least 2-3 new significant skills 8. Have taken up to 80 hours (2 weeks) training per year	8

10 Key Competencies for Assessing Program Specific Outcomes:

PSO	NBA statement / Vital features	No. of vital features
PSO1	**Understand, design and analyze computer programs in the areas related to Algorithms, System Software, Web design, Big data, Artificial Intelligence, Machine Learning and Networking.** 1. Identify the need and problem specific constraints 2. Develop computer programs related to Algorithms for specific problem / project. 3. Develop data centric applications using the concepts of Algorithms, System Software, Web design, Big data, Artificial Intelligence, Machine Learning and Networking. 4. Design and analyze algorithms for problems. 5. Use data structures for developing solutions. 6. Apply appropriate algorithms for data processing.	6
PSO2	**Focus on improving software reliability, network security / information retrieval systems.** 1. Design and develop software applications with a focus on high security and reliability. 2. Design and develop information retrieval systems for specific applications.	2
PSO3	**Make use of modern computer tools for creating innovative career paths, to be an entrepreneur and desire for higher studies.** 1. Identify the technical skills and Knowledge on advanced frameworks and platforms necessary for engineering practice and higher studies. 2. Extend the knowledge to become an entrepreneur	2

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

Courses offered in Computer Science and Engineering Curriculum (UG20) 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 Semester B. Tech																
AHSC02	Linear Algebra and Calculus	✓	✓													
AHSC06	Chemistry	✓	✓					✓								
AEEC01	Basic Electrical Engineering	✓	✓											✓		
ACSC01	Phyton Programming	✓	✓	✓		✓					✓		✓	✓		✓
AEEC04	Basic Electrical Engineering Laboratory	✓							✓	✓	✓		✓	✓		
ACSC02	Python Programming Laboratory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
AMEC04	Engineering Work shop Practice	✓		✓			✓	✓		✓		✓				✓
II SEMESTER																
AHSC01	English										✓					
AHSC08	Prabability and Statistics	✓	✓		✓	✓										
AHSC09	Applied Physics	✓	✓		✓											
ACSC04	Programming for Problem Solving using C	✓	✓	✓		✓					✓		✓	✓		✓
AHSC04	English Language and communication Skills Laboratory									✓	✓					
AHSC05	Physics Laboratory	✓	✓		✓											
ACSC05	Programming for Problem Solving using C Laboratory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
III SEMESTER																
AITC01	Discrete Mathematical Structures	✓	✓	✓										✓		

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
ACSC07	Computer Organization and Architecture	✓	✓	✓	✓						✓		✓	✓		✓
ACSC08	Data Structures	✓	✓	✓	✓	✓					✓		✓	✓	✓	✓
AITC02	Programming with Objects	✓	✓		✓	✓							✓	✓		✓
AECC08	Analog and Digital Electronics	✓	✓	✓							✓		✓	✓		
ACSC09	ExEEd-Prototype/Design Building										✓			✓	✓	✓
AITC03	Programming with Objects Laboratory			✓		✓	✓				✓		✓	✓	✓	✓
ACSC11	Advanced Python Programming Laboratory	✓	✓	✓	✓	✓				✓	✓				✓	
ACSC10	Data Structures Laboratory	✓	✓	✓		✓	✓				✓		✓	✓	✓	✓
IV SEMESTER																
AITC04	Theory of Computation	✓	✓	✓	✓									✓		✓
ACSC12	Operating Systems	✓	✓	✓	✓						✓		✓	✓	✓	✓
AITC05	Database Management Systems	✓	✓	✓	✓						✓			✓	✓	✓
ACSC13	Design and Analysis of Algorithms	✓	✓	✓	✓								✓	✓		
AHSC13	Business Econamics and Financial Analysis	✓	✓						✓	✓		✓				✓
ACSC14	ExEEd -Fabrication/Model Development		✓	✓							✓			✓	✓	✓
AITC07	Database Management Systems Laboratory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
ACSC15	Design and Analysis of algorithms Laboratory		✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓
ACSC16	Linux Programming Laboratory	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
V SEMESTER																
AITC06	Computer Networks	✓	✓	✓	✓						✓		✓	✓		✓
ACSC18	Compiler Design	✓	✓	✓		✓								✓		✓
ACSC19	Object Oriented Software Engineering	✓	✓	✓	✓	✓					✓		✓	✓	✓	✓
AITC09	Web Application Development	✓	✓	✓		✓								✓	✓	✓
ACSC20	ExEEd - Project Based Learningl		✓	✓							✓			✓	✓	✓
ACSC21	Object Oriented Software Design Laboratory	✓	✓	✓	✓	✓								✓	✓	✓
AITC10	web Application Devolopment Laboratory		✓	✓	✓		✓							✓	✓	✓
VI SEMESTER																
ACIC01	Data Mining and Knowledge Discovery	✓	✓	✓		✓				✓	✓			✓	✓	✓
ACIC02	Software Quality Assurence and Testing	✓	✓	✓										✓		✓
ACIC03	Network and Web Security	✓	✓	✓										✓	✓	✓
ACSC27	EXEED- Project Based Learning	✓	✓	✓							✓			✓		

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
ACIC08	Data Mining and Kowledge Discovery Laboratory	✓	✓	✓		✓					✓			✓	✓	✓
ACIC09	Software Testing Laboratory	✓	✓	✓		✓					✓			✓	✓	✓
VII SEMESTER																
ACSC30	Clod Application Devolopment	✓	✓	✓							✓		✓	✓	✓	✓
ACSC31	Big Data and Analytics	✓	✓	✓		✓							✓	✓	✓	✓
ACSC33	Cloud Application Devolopment Laboratory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
ACSC34	Big Data and Analytics Laboratory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
ACSC35	Project Work (Phase-1)	✓	✓	✓	✓	✓	✓		✓		✓		✓	✓	✓	✓
VIII SEMESTER																
ACSC39	Project Work (Phase-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) Alternate Assessment Tools (AAT)
iii) Semester end examination (SEE)
iv) Laboratory and project work
v) Course exit survey
vi) Program exit survey
vii) Alumni survey
viii) Employer survey
ix) Course expert committee
x) Program Assessment and Quality Improvement Committee (PAQIC)
xi) Department Advisory Board (DAB)
xii) Faculty meetings

xiii) Professional societies

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 Alternate Assessment Tools (AAT)

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

12.3 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 department advisory board (DAB) and to the principal for taking necessary actions to better the course for subsequent semesters.

12.4 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.

12.5 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 DAC meetings.

12.6 Programme Exit Survey

The programme exist questionnaire form is to be filled by all the students leaving the institution. The questionnaire is designed in such a way to gather information from the students regarding the program educational objectives, solicit about program experiences, carrier choices, as well as any suggestions and comments for the improvement of the program. The opinions expressed in exit interview forms are reviewed by the DAC for implementation purposes.

12.7 Alumni Survey

The survey asks former students of the department about the status of their employment and further education, perceptions of institutional emphasis, estimated gains in knowledge and skills, involvement a sunder graduate student, and continuing involvement with Institute of Aeronautical Engineering. This survey is administered every three years. The data obtained will be analyzed and used in continuous improvement.

12.8 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 e is also to identify gaps in technical and vocational skills, need for required training practices to fill these gaps and criteria for hiring new employees. These employer surveys are reviewed by the College Academic Council (CAC) to affect the present curriculum to suit the requirement so the employer.

12.9 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 review the course full stack content developed by the respective course coordinator.

12.10 Programme Assessment and Quality Improvement Committee (PAQIC)

PAC Monitors the achievements of Program Outcomes (POs), Program Specific Outcomes (PSOs) and Program Educational Objectives (PEOs). It will evaluate the program effectiveness and proposes the necessary changes. It also prepares the periodic reports on program activities, progress, status or other special reports for management. It also motives the faculty and students towards attending workshops, developing projects, working models, paper publications and engaging in research activities.

12.11 Department Advisory Board (DAB)

Departmental Advisory Board plays an important role in the development of the department. Department level Advisory Board will be established for providing guidance and direction for qualitative growth of the department. The Board interacts and maintains liaison with key stakeholders. DAB will Monitor the progress of the program and develop or recommend the new or revised goals and objectives for the program. Also, the DAB will review and analyze the gaps between curriculum and Industry requirement and gives necessary feedback or advices to be taken to improve the curriculum.

12.12 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 fortnight for ensuring the implementation of DAB's suggestions and guidelines. All these proceedings are recorded and kept for the availability of all faculties.

12.13 Professional Societies

The importance of professional societies like IEEE, IETE, ISTE, IE (I) etc., are explained to the students and they are encouraged to become members of the above to carry out their continuous 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) whereas 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 & AAT)	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 the various assessments and examinations. These assessment methods provide evidence that a student has command over a specific course, content, or skill, or that the students work demonstrates a specific quality such as creativity, analysis, or synthesis.

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

- Continuous internal examination, semester end examinations, AAT (includes assignment, 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 POs.
- Performance in AAT is indicative of the student's communication skills.

S No	Courses	Components	Frequency	Max. Marks	Evidence
1	Core / Elective	Continuous Internal Examination	Twice in a semester	20	Answer script
		Alternative Assessment Tools (AAT)	Twice in a semester	10	Video / Quiz / assignment
		Semester End Examination	Once in a semester	70	Answer script

S No	Courses	Components	Frequency	Max. Marks	Evidence
2	Laboratory	Conduction of experiment	Once in a week	4	Work sheets
		Observation	Once in a week	4	Work sheets
		Result	Once in a week	4	Work sheets
		Record	Once in a week	4	Work sheets
		Viva	Once in a week	4	Work sheets
		Internal laboratory assessment	Once in a semester	10	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	Comprehensive Examination	Written examination (objective type)	Once in a semester	50	Online assessment
		Oral examination	Once in a Semester	50	Viva

13.2 Indirect Assessment:

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 Indirect 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 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 Program Articulation Matrix are considered for calculation of direct attainment of PO/PSOs.

14.1 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.

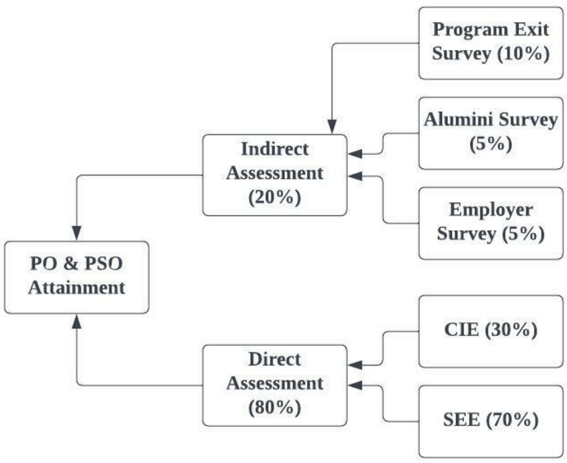


FIGURE 4: Evaluation process of POs/PSOs attainment

15 Course Description:

The “Course Description” provides general information regarding the topics and content addressed in the course. A sample course description is given in Annexure – I for the reference.

The “Course Description” contains the following contents:

- Course Overview
- Prerequisite(s)
- Marks Distribution
- Content delivery / Instructional methodologies
- Evaluation Methodology
- Course Objectives
- Course Outcomes
- 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
- Syllabus
- List of Text Books / References / Websites
- Course Plan

Course Decsription (Annexure-I) :

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043
COURSE DESCRIPTION

Department	**COMPUTER SCIENCE AND ENGINEERING**				
Course Title	**THEORY OF COMPUTATION**				
Course Code	AITC04				
Program	B.Tech				
Semester	IV				
Course Type	Core				
Regulation	UG-20				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	1	4	-	-
Course Coordinator	Ms. V.Divyavani, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AHS010	II	Probability and Statistics.
B.Tech	ACS002	II	Data Structures
B.Tech	AHS013	III	Discrete Mathematical Structures

II COURSE OVERVIEW:

This course focuses on infinite languages in finite ways, and classifies machines by their power to recognize. It includes finite automata, regular grammar, push down automata, context free grammars, and Turing machines It is applicable in designing phrasing and lexical analysis of a compiler, genetic programming and recursively enumerable languages.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Theory of computation	70 Marks	30 Marks	100

IV CONTENT DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	Power Point Presentations	✓	Chalk & Talk	x	Assignments	x	MOOC
✓	Open Ended Experiments	x	Seminars	x	Mini Project	✓	Videos
x	Others						

V EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), and 10 marks for Alternative Assessment Tool (AAT).

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

The expected percentage of cognitive level of the questions is broadly based on the criteria given in below Table.

Percentage of Cognitive Level	Blooms Taxonomy Level
10%	Remember
60 %	Understand
20%	Apply
10%	Analyze

Continuous Internal Assessment (CIA):
CIA is conducted for a total of 30 marks, with 20 marks for continuous internal examination (CIE) and 10 marks for Alternative Assessment Tool (AAT).

Component		Marks	Total Marks
CIA	Continuous Internal Examination – 1 (Mid-term)	10	30
	Continuous Internal Examination – 2 (Mid-term)	10	
	AAT-1	5	
	AAT-2	5	
SEE	Semester End Examination (SEE)	70	70
Total Marks			100

Continuous Internal Examination (CIE):
Two CIE exams shall be conducted at the end of the 8^{th} and 16^{th} week of the semester respectively for 10 marks each of 2 hours duration consisting of five descriptive type questions out of which four questions have to be answered.

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

Concept Video	Tech-talk	Complex Problem Solving
40%	40%	20%

VI COURSE OBJECTIVES:

The students will try to learn:

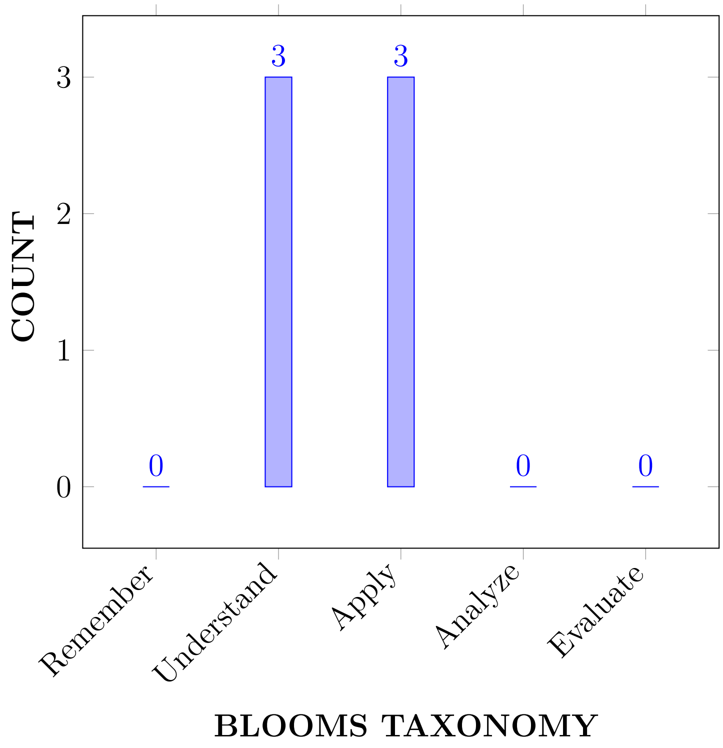
I	The fundamental knowledge of automata theory which is used to solve computational problems
II	The reorganization of context free language for processing infinite information using push down automata.
III	The computer based algorithms with the help of an abstract machine to solve recursively Enumerable problems

VII COURSE OUTCOMES:

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

CO 1	**Make use of** deterministic finite automata and non deterministic finite automata for modeling lexical analysis and text editors.	Apply
CO 2	**Extend** regular expressions and regular grammars for parsing and designing programming languages.	Under-stand
CO 3	**Illusrate** the pumping lemma on regular and context free languages for perform negative test .	Under-stand
CO 4	**Demonstarte** context free grammars, normal forms for generating patterns of strings and minimize the ambiguity in parsing the given strings.	Under-stand
CO 5	**Construct** push down automata for context free languages for developing parsing phase of a compiler.	Apply
CO 6	**Apply** Turing machines and Linear bounded automata for recognizing the languages,complex problems.	Apply

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO 2	**Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

Program Outcomes	
PO 3	**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
PO 4	**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.
PO 5	**Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern Engineering and IT tools including prediction and modelling to complex Engineering activities with an understanding of the limitations
PO 6	**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.
PO 7	**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.
PO 8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO 9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO 10	**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.
PO 11	**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.
PO 12	**Life-Long Learning:** Recognize the need for and having the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

IX HOW PROGRAM OUTCOMES ARE ASSESSED:

PROGRAM OUTCOMES		Strength	Proficiency Assessed by
PO 1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	CIE / SEE
PO 2	**Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	2.5	AAT

PROGRAM OUTCOMES		Strength	Proficiency Assessed by
PO 3	**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	2.5	SEE / AAT
PO 4	**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	CIE / Quiz / AAT

3 = High; 2 = Medium; 1 = Low

X HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

PROGRAM SPECIFIC OUTCOMES		Strength	Proficiency Assessed by
PSO 1	Understand, design and analyze computer programs in the areas related to Algorithms, System Software, Web design, Big data, Artificial Intelligence, Machine Learning and Networking.	2.3	Group discussion/ Short term courses
PSO 3	Make use of modern computer tools for creating innovative career paths, to be an entrepreneur and desire for higher studies.	2.0	Research papers/ Industry exposure

3 = High; 2 = Medium; 1 = Low

XI MAPPING OF EACH CO WITH PO(s),PSO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES												PSO'S		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO 1	✓	-	-	-	-	-	-	-	-	-	-		-	-	✓
CO 2	✓	-	-	-	-	-	-	-	-	-	-	-	✓	-	-
CO 3	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-
CO 4	✓	✓	-	-	-	-	-	-	-	-	-		✓	-	-
CO 5	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	✓
CO 6	✓	✓	✓	✓		-	-	-	-	-	-	-	✓	-	

XII JUSTIFICATIONS FOR CO – PO/ PSO MAPPING -DIRECT:

Course Outcomes	PO'S PSO'S	Justification for mapping (Students will be able to)	No. of Key competencies matched.
CO 1	PO 1	Solve the lexical analysis and text editor's using deterministic finite automata and non- deterministic finite automata using the principles of mathematical principles and scientific principles.	2
	PSO 3	Demonstrate the basic text editors in real world software, using industry standard tools and collaboration techniques in the field of computational programming.	1
CO 2	PO 1	Understand the basics of regular expressions and regular grammars, its types and properties for applying mathematical principles and scientific principles.	2
	PSO 1	Make use of the concept of regular expressions and regular grammars for developing algorithms of machine learning and networking concepts.	3
CO 3	PO 1	Find an optimized solution for the given problem using pumping lemma by applying the knowledge of mathematical principles and computer engineering methodologies.	2
	PO 2	Understand the given problem and develop the solution using pumping lemma from the provided information and interpret of results for validation.	5
	PO 3	Explain and demonstrate the pumping lemma, by investigate and define a problem and identify constraints ,Understand customer and user needs, Manage the design process and evaluate outcomes.	5
CO 4	PO 1	Describe the role of Ambiguity in construction of context free grammars by understanding mathematical principles and scientific principles.	2
	PO 2	Understand the given problem and analyze the grammar and eliminate ambiguity using derivation trees by model,design,document the results for interpretation.	6
	PSO 1	Understand the normalization techniques in the area related to parsing desire for higher studies in field of compiler design, machine Learning and data science.	3
CO 5	PO 1	Describe acceptance of context free language by final state and by empty stack problems by understanding mathematical principles, engineering methodologies and scientific principles.	3
	PO 2	Understand equivalence of context free language and pushdown automata for validation , model, design of inter conversion for solving the given problem related to engineering from the provided information , data and documentation.	6

Course Outcomes	PO'S PSO'S	Justification for mapping (Students will be able to)	No. of Key competencies matched.
	PSO 3	Understand the principle of languages , grammars for computational programming to achieve engineering objectives.	1
CO 6	PO 1	Describe the recursively enumerable languages and churchs hypothesis using mathematical principles and scientific principles.	3
	PO 2	Understand the given problem statement and formulate the (complex) engineering problems in the Design and Model of Turing machine in reaching substantiated conclusions by the interpretation of results.	5
	PO 3	Make Use of Turing machines to develop programs (define problem)for identify the solution (innovative) of complex engineering problems which satisfy the user constraints.	6
	PO 4	Ability to identify ,classify and describe the performance of turing machine by using analytical methods and modeling techniques.	4
	PSO 1	Analyze computable functions in the areas related to simulation of Turing machine, software testing, high performance computing, machine learning, software engineering and computer networks	6

XIII TOTAL COUNT OF KEY COMPETENCIES FOR CO – PO/ PSO MAPPING:

COURSE OUTCOMES	PROGRAM OUTCOMES												PSO'S		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO 1	2	-	-	-	-	-	-	-	-	-	-		-	-	1
CO 2	2	-	-	-	-	-	-	-	-	-	-	-	3	-	-
CO 3	2	5	5	-	-	-	-	-	-	-	-	-	-	-	-
CO 4	2	6	-	-		-	-	-	-	-	-		3	-	-
CO 5	3	6	-	-	-	-	-	-	-	-	-	-	-	-	1
CO 6	3	5	6	5	-	-	-	-	-	-	-		6	-	-

XIV PERCENTAGE OF KEY COMPETENCIES FOR CO – PO/ PSO

COURSE OUTCOMES	PROGRAM OUTCOMES												PSO'S		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO 1	66.7	-	-	-	-	-	-	-	-	-	-		-	-	50.0
CO 2	66.7	-	-	-	-	-	-	-	-	-	-	-	50.0	-	-
CO 3	66.7	50.0	50.0	-	-	-	-	-	-	-	-	-	-	-	-
CO 4	66.7	60.0	-	-		-	-	-	-	-	-		50.0	-	-
CO 5	100	60	-	-	-	-	-	-	-	-	-	-	-	-	50.0
CO 6	100	50	60	55.0		-	-	-	-	-	-		100	-	-

XV COURSE ARTICULATION MATRIX (PO / PSO MAPPING):

CO'S and PO'S and 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 - $0 \leq$ C$\leq$ 5% – No correlation
1 -5 <C$\leq$ 40% – Low/ Slight
2 - 40 % <C < 60% –Moderate
3 - 60% $\leq$ C < 100% – Substantial /High

COURSE OUTCOMES	PROGRAM OUTCOMES												PSO'S		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO 1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2
CO 2	3	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO 3	3	2	2	-	-	-	-	-	-	-	-	-	-	-	-
CO 4	3	3	-	-	-	-	-	-	-	-	-	-	2	-	-
CO 5	3	3	-	-	-	-	-	-	-	-	-	-	-	-	2
CO 6	3	2	3	2	-	-	-	-	-	-	-	-	3	-	-
TOTAL	18	10	5	2	-	-	-	-	-	-	-	-	7	-	4
AVERAGE	3.0	2.5	2.5	2.0	-	-	-	-	-	-	-	-	2.3	0	2.0

XVI ASSESSMENT METHODOLOGY-DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminars	-
Laboratory Practices	-	Student Viva	-	Certification	-
Term Paper	-	5 Minutes Video	✓	Open Ended Experiments	✓
Assignments					

XVII ASSESSMENT METHODOLOGY-INDIRECT:

✓	Early Semester Feedback	✓	End Semester OBE Feedback
X	Assessment of Mini Projects by Experts		

XVIII SYLLABUS:

MODULE I	**FINITE AUTOMATA**
	Fundamentals: Alphabet, strings, language, operations; Introduction to finite automata: The central concepts of automata theory, deterministic finite automata, nondeterministic finite automata, an application of finite automata, finite automata with and without epsilon transitions, Conversion of NFA to DFA, Moore and Melay Machines.
MODULE II	**REGULAR LANGUAGES**

	Regular sets, regular expressions, identity rules, constructing finite automata for a given regular expressions, conversion of finite automata to regular expressions, pumping lemma of regular sets, closure properties of regular sets (proofs not required), regular grammars-right linear and left linear grammars, equivalence between regular linear grammar and finite automata, inter conversion.
MODULE III	**CONTEXT FREE GRAMMARS**
	Context free grammars and languages: Context free grammar, derivation trees, sentential forms, right most and leftmost derivation of strings, applications. Ambiguity in context free grammars, minimization of context free grammars, Chomsky normal form, Greibach normal form, pumping lemma for context free languages, enumeration of properties of context free language (proofs omitted)
MODULE IV	**PUSHDOWN AUTOMATA**
	Pushdown automata, definition, model, acceptance of context free language, acceptance by final state and acceptance by empty stack and its equivalence, equivalence of context free language and pushdown automata, inter conversion;(Proofs not required); Introduction to deterministic context free languages and deterministic pushdown automata.
MODULE V	**TURING MACHINE**
	Turing machine: Turing machine, definition, model, design of Turing machine, computable functions, recursivey enumerable languages, Church's hypothesis, counter machine, types of Turing machines (proofs not required), linear bounded automata and context sensitive language, Chomsky hierarchy of languages.

TEXTBOOKS

1. John E. Hopcroft , Rajeev Motwani, Jeffrey D. Ullman, Introduction to Automata, Theory, Languages and Computation, Pearson Education, 3rd Edition, 2007. .

REFERENCE BOOKS:

1. John C Martin, Introduction to Languages and Automata Theory, Tata McGraw Hill, 3rd Edition, 2017
2. Daniel I.A. Cohen, Introduction to Computer Theory, John Wiley Sons, 2nd Edition, 2004.

COURSE WEB PAGE:

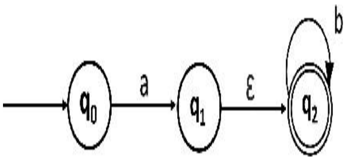
https://nptel.ac.in/courses/106103070

XIX COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
OBE DISCUSSION			
1	In Outcome-Based Education (OBE), we discussed about course delivery assessment that are planned to achieve stated objectives and outcomes. We will focuses on measuring student performance i.e. outcomes at different levels. Course outcomes(CO),Program Outcomes(PO)and Program Specific Outcomes(PSO) and also mapping of CO's to PO's		

	PSO's and their attainments are discussed.		
CONTENT DELIVERY (THEORY)			
1	Alphabet, strings, language and operations	CO1	T1:1.5-1.6
2	finite automata and concepts of automata theory	CO1	T1:2.1-2.2, R2:38-64
3	Demonstrate the behavior of deterministic finite automata	CO 1	T1:2.2-2.3
4-6	Understand the functionality of non- deterministic finite automata and Finite automata with epsilon transitions.	CO 1	T1:2.3-2.4, R1:3.1-3.3, R2:142-148
7	application of finite automata,Conversion of NFA to DFA, Moore and Melay Machines.	CO 1	T1:2.3-2.4, R1:3.1-3.3, R2:142-148
8-10	understand the Regular sets, regular expressions, identity rules	CO 2	T1: 3.1-3.2
11-13	finite automata for a given regular expressions, finite automata to regular expressions	CO 2	T1: 3.1-3.2
14-15	find the pumping lemma of regular sets, regular grammars, right linear and left linear grammars	CO 3	T1: 4.1-4.2
16-19	Regular grammars-right linear and left linear grammars	CO 4	T1: 4.4-4.5
20-22	regular linear grammar and finite automata, inter conversion.	CO 2	T1: 4.4-4.5
23-24	Apply Context free grammar on derivation trees	CO 4	T1: 5.1-5.5, R1:4.2-4.4
25-27	sentential forms, right most and leftmost derivation of strings	CO 4	T1: 5.1-5.5, R1:4.2-4.4
28-29	Ambiguity in context free grammars	CO 4	T1: 5.1-5.5, R1:4.2-4.4
30-32	Understand Minimization of context free grammars, Chomsky normal form, Greibach normal form	CO 4	T1: 7.4-7.5, R1:6.1-6.2
33-34	Pumping lemma for context free languages, properties	CO 3	T1: 7.4-7.5, R1:6.1-6.2
35-37	Apply the push down automata for acceptance of context free Languages	CO 5	T1: 6.1-6.2, R1:5.2-5.4
38-41	push down automata for given context free languages	CO 5	T1: 6.1-6.2, R1:5.2-5.4
42-43	acceptance by empty stack and its Equivalence.	CO 5	T1: 6.1-6.2, R1:5.2-5.4
44-45	Describe Equivalence of context free language and pushdown automata	CO 5	T1: 6.3-6.4
46-47	inter conversion, deterministic push down automata.	CO 5	T1: 6.3-6.4
48-53	Describe Turing machine, definition, model, computable functions	CO 6	T1: 8.1-8.2, R1:7.2-7.4
54-56	Apply Recursively enumerable languages	CO 6	T1: 8.2-8.6, R1:7.5-7.6
57-58	Types of Turing machines and Church's hypothesis.	CO 6	T1: 8.2-8.6, R1:7.5-7.6
59-60	Linear bounded automata and context sensitive language.	CO 6	T1:9.1-9.8, R2:551-560
61-62	Chomsky hierarchy of languages.	CO 6	T1:9.1-9.8, R2:551-560

PROBLEM SOLVING/ CASE STUDIES			
1	Describe a DFA for the following language L={w/|w | mod5=0,w belongs to (a,b)*} L={w/|w | mod5=1,w belongs to (a,b)*}	CO 1	T1:2.3-2.4, R1:3.1-3.3
2	Convert NFA with ϵ to equivalent NFA M=({q0,q1,q2},{0,1,2}, δ, q0, {q2}) where δ is given by [δ (q0,0)={q0}, δ (q0,1)=ϕ, δ (q0,2)=ϕ, δ(q0, ϵ)=q1] [δ (q1,0)=ϕ, δ (q1,1)=q1 , δ (q1,2)=ϕ ,δ (q1, ϵ)=q2] [δ (q2,0)=ϕ, δ (q2,1)= ϕ , δ (q2,2)= {q2},δ (q2, ϵ)= ϕ]	CO1	T1:2.3-2.4, R1:3.1-3.3
3	Convert NFA with ϵ to equivalent DFA 	CO 1	T1:2.3-2.4, R1:3.1-3.3
4	Describe Pumping Lemma for Regular Languages. Prove that the language L = {a^n/ n is a n^5} is not regular	CO 3	T1: 7.4-7.5, R1:6.1-6.2
5	Convert the following automata into Regular expression M=({q1,q2,q3},{0,1}, δ, q1, {q2,q3}) where δ is given by [δ (q1,0)={q2}, δ (q1,1)={q3}] [δ (q2,0)={q1}, δ (q2,1)={q3}] [δ (q3,0)={q2}, δ (q3,1)= {q2}]	CO 2	T1: 3.1-3.2
6	Describe the DFA Transition diagram for equivalent Regular expression (ab+a) *(aa+b)	CO 1	T1:3.1-3.2
7	Convert the following grammar into GNF S→ABA/AB/BA/AA/B A→aA/a, B→bB/b	CO 4	T1: 7.4-7.5, R1:6.1-6.2
8	Describe the context free grammars in the four tuple form.(V,T,P,S) for the given languages on $\sum$={a,b} i. All strings having at least two a's ii. All possible strings not containing triple b's	CO 4	T1: 7.4-7.5, R1:6.1-6.2
9	Describe the steps to show the following is not CFG. { $a^m b^n c^p$ | m< n or n< p}	CO 4	T1: 7.4-7.5, R1:6.1-6.2
10	Construct PDA for equal number of x's and y's. eg: xyyxxy	CO 5	T1: 6.1-6.2, R1:5.2-5.4
11	Construct NDPDA for L = { W$\neq W^R$ /W$\in (X+Y)^*$}	CO 5	T1: 6.1-6.2, R1:5.2-5.4
12	Construct DPDA for L = { W$\neq W^R$ /W$\in (X+Y)^*$}	CO 5	T1: 6.1-6.2, R1:5.2-5.4
13	Construct a Turing Machine that accepts the language L = { $a^{2n}b^n$ |n$\geq$0}.Give the transition diagram for the Turing Machine obtained.	CO 6	T1: 8.2-8.6, R1:7.5-7.6
14	Construct a Turing Machine to accept the following languages L = {$w^n x^n y^n z^n$ | n$\geq$1}	CO 6	T1:8.2-8.6, R1:7.5-7.6
15	Design a Turing Machine that accepts the language denoted by regular expression (000)*	CO 6	T1:8.2-8.6, R1:7.5-7.6
DISCUSSION ON DEFINITION AND TERMINOLOGY			
1	Alphabet, strings, language and operations	CO 1	T1:1.5-1.6
2	understand the Regular sets, regular expressions, identity rules	CO 2	T1:3.1-3.2

3	Understand Minimization of context free grammars, Chomsky normal form, Greibach normal form	CO 4	T1:7.4-7.5, R1:6.1-6.2
4	push down automata for given context free languages	CO 5	T1:6.1-6.2, R1:5.2-5.4
5	Types of Turing machines and Church's hypothesis.	CO 6	T1:8.2-8.6, R1:7.5-7.6
	DISCUSSION ON QUESTION BANK		
1	Describe the DFA with the set of strings having "aaa as a substring over an alphabet $\sum$ ={a,b}.	CO 1	T1:1.5-1.6
2	Convert Regular Expression (11+0)*(00+1)* to Finite Automata.	CO 2	T1:3.1-3.2
3	Describe a CFG for the languages L={a^ib^j | i≤2j}	CO 4	T1:7.4-7.5, R1:6.1-6.2
4	Define the NPDA(Nondeterministic PDA) and DPDA(deterministic PDA) equivalent? Illustrate with an example.	CO 5	T1:6.1-6.2, R1:5.2-5.4
5	Describe a Turing Machine. With a neat diagram explain the working of a Turing Machine.	CO 6	T1: 8.2-8.6, R1:7.5-7.6

Signature of Course Coordinator
HOD,CSE