IARE
INSTITUTE OF AERONAUTICAL ENGINEERING

Outcome Based Education (OBE) Manual

Department of Information Technology
Regulation: R16

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. 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

Vision

The Department envisions to become a Center of Excellence in Information Technology with a strong teaching and research environment that produces competent graduates and to inculcate traits to make them not only good professionals but also kind, committed and socially oriented human beings.

Mission

To promote a teaching and learning process that includes latest advancements in information technology, that provides strong practical base for the graduates to make them excellent human capital for sustainable competitive edge and social relevance by inculcating the philosophy of continuous learning and innovation in the core areas.

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.

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 Information Technology:
To prepare the graduates for a successful career to meet the diversified needs of industry, academia and research.

Program Educational Objective – II: Industrial awareness and research:
To equip graduates with a solid foundation in discrete mathematical and engineering fundamentals required to develop problem solving ability in complex engineering design.

Program Educational Objective – III: Successful employment and professional ethics:
To train students to comprehend, analyze, design and provide ability to create novel products and technologies that give solution-frameworks to real world problems.

Program Educational Objective – IV: Being a leader in professional and societal environment:
To inculcate in graduates the qualities of leadership in technology innovation and entrepreneurship with effective communication skills, teamwork, ethics and to create ability for life-long learning needed in a successful professional career.

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

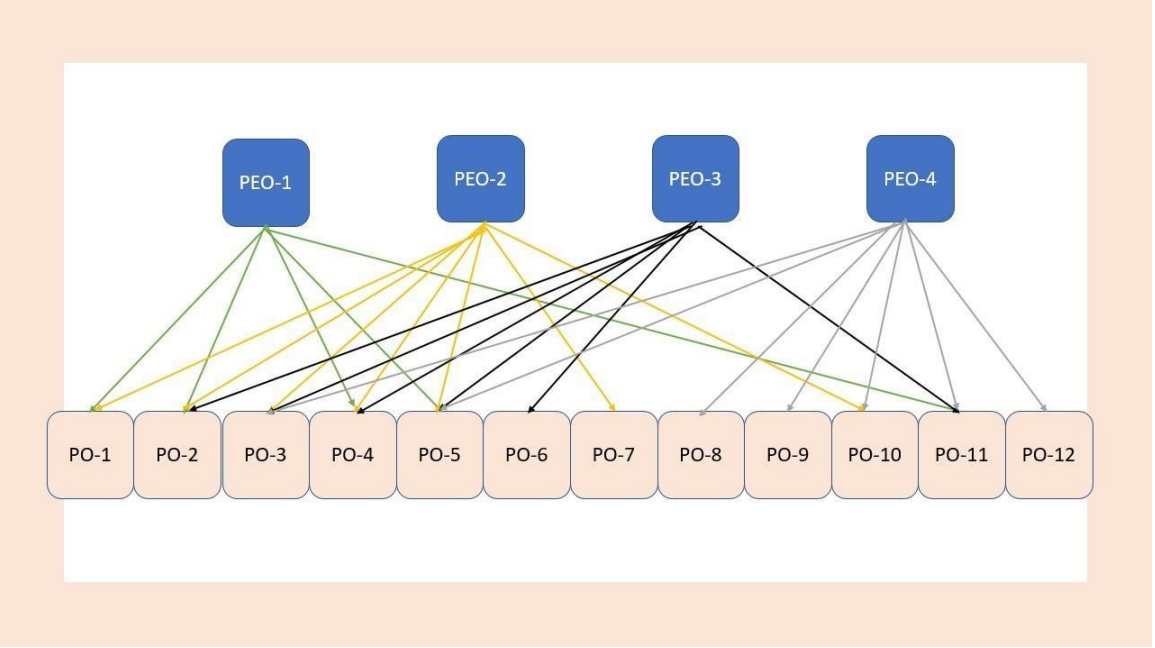


FIGURE 1: Correlation between the PEOs and the POs

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

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

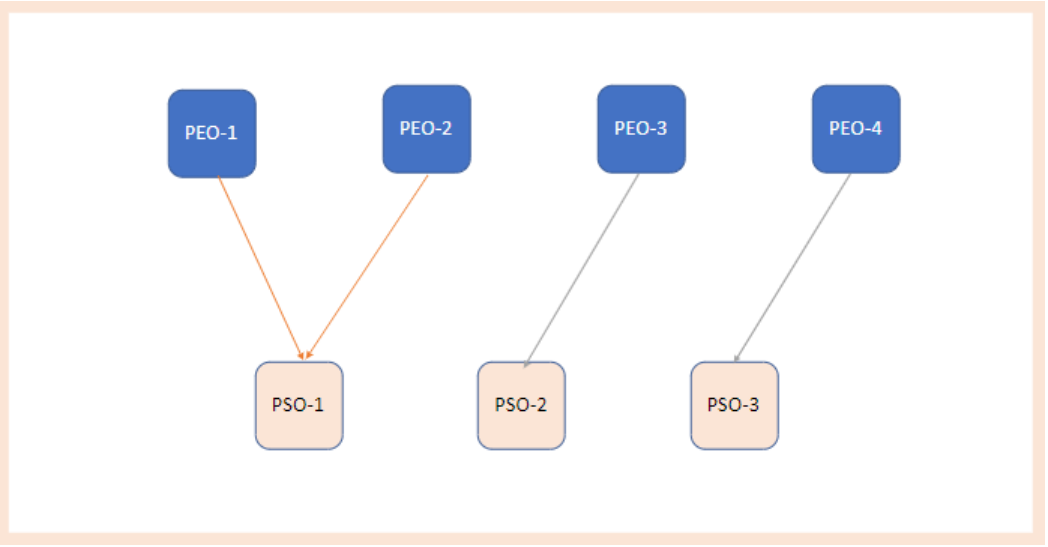


FIGURE 2: Correlation between the PEOs and the PSOs

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 (IT) - PROGRAM OUTCOMES (PO's)	
A graduate of the Information Technology 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 Information Technology is given below.

B. Tech (IT) - PROGRAM SPECIFIC OUTCOMES (PSO's)	
A graduate of the Information Technology Program will demonstrate:	
PSO1	Design next-generation computer systems, networking devices, search engines, soft computing and intelligent systems, web browsers, and knowledge discovery tools.
PSO2	Focus on mobile and web applications development and learn the emerging technologies and frameworks in demand with employers and contemporary challenges.
PSO3	Practical experience in shipping real world software, using industry standard tools and collaboration techniques will equip to secure and succeed in first job upon graduation in IT industry.

5 Relation between the Program Educational Objectives and the POs

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

PEO's→ ↓ PO's		(1) Excellence in Career	(2) Profession Effec-tiveness	(3) l Problem Solving	(4) Exercising Leadership
PO1	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.			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	
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		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

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

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:

PEO's→ ↓ PSO's		Excellence in Career	Profession Effec-tiveness	l Problem Solving	Exercising Leadership
PSO1	Design next-generation computer systems, net-working devices, search engines, soft computing and intelligent systems, web browsers, and knowledge discovery tools.		3		2
PSO2	Focus on mobile and web applications development and learn the emerging technologies and frame-works in demand with employers and contempo-rary challenges.	3		3	2
PSO3	Practical experience in shipping real world soft-ware, using industry stan-dard tools and collabora-tion techniques will equip to secure and succeed in first job upon graduation in IT industry.	2	3	2	

Relationship between Program Specific Outcomes and Program Educational Objectives

Key: 3 = High; 2 = Medium; 1= Low

Note:

- The assessment process of POs and PSOs can be direct or indirect.
- The direct assessment will be done through interim assessment by conducting continuous internal exam and semester end exams.
- The indirect assessment on the other hand could be done through student's 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

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

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

S No	Condition	Observable Behaviour	Standard
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>Typ</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><td rowspan="7">Non-Technical</td><td>PO6</td><td colspan="3" rowspan="7">Thumb Rule:
If Bloom's L1 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign 1.
If Bloom's L2 to L3 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign 2.
If Bloom's L4 to L6 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign 3</td></tr>
<tr><td>PO7</td></tr>
<tr><td>PO8</td></tr>
<tr><td>PO9</td></tr>
<tr><td>PO10</td></tr>
<tr><td>PO11</td></tr>
<tr><td>PO12</td></tr>
</table>

At the end, the 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

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

$$1 - 5 < C \leqq 40\% \text{ - Low / Slight.}$$

$$2 - 40\% < C < 60\% \text{ - Moderate}$$

$$3 - 60\% \leqq C < 100\% \text{ - Substantial / High}$$

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
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	10

PO	NBA statement / Vital features	No. of vital features
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 con- siderations 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 includingproduction, operation, maintenance and disposal 6. Manage the design process and evaluate outcomes 7. Knowledge and understanding of commercial and economic con-text 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 pro-mote 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 stan-dards 6. Awareness of quality issues 7. Ability to work with technical uncertainty. 8. Understanding of engineering principles and the ability to applythem to analyse key engineering processes 9. Ability to identify, classify and describe the performance of sys- tems and components through the use of analytical methods and modeling techniques 10. Ability to apply quantitative methods and computer software rel- evant to their engineering discipline, in order to solve engineeringproblems 11. Understanding of and ability to apply a systems approach to en-gineering 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 eth-ical 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 friend- ships 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 Environments (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	Design next-generation computer systems, networking devices, search engines, soft computing and intelligent systems, web browsers, and knowledge discovery tools. 1. Ability to develop next generation computer systems. 2. Acquire knowledge in designing of search engines. 3. Understanding how all the elements of the network link together (routers,switches, servers, desktops, laptops, and printers). 4. Acquire knowledge of soft computing techniques for solving complex computational problems. 5. Acquire knowledge of data mining techniques. 6. Design and develop user interfaces for the android platform	6
PSO2	Focus on mobile and web applications development and learn the emerging technologies and frameworks in demand with employers and contemporary challenges. 1. Ability to develop website models. 2. Explore historical, current, and emerging techniques and technologies for lifelong learning and professional development	2

PSO	NBA statement / Vital features	No. of vital features
PSO3	Practical experience in shipping real world software, using industry standard tools and collaboration techniques will equip to secure and succeed in first job upon graduation in IT industry. 1. Acquire practical experience in languages and software tools for developing real world software. 2. Ability to provide security for the developed software.	2

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

Courses offered in Information Technology Curriculum (IARE-R16) and POs/PSOsattained 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																
AHS002	Linear Algebra and Ordinary Differential Equations	✓	✓													
AHS003	Computational Mathematics and Integral Calculus	✓	✓													
AHS006	Engineering Physics	✓	✓		✓											✓
AHS005	Engineering Chemistry	✓	✓					✓								

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
AHS104	Engineering Physics and Chemistry Laboratory	✓	✓	✓	✓			✓						✓	✓	
AME103	Computer Aided Engineering Drawing	✓	✓	✓	✓	✓								✓	✓	
AHS102	Computational Mathematics Laboratory	✓	✓	✓		✓							✓	✓	✓	
ACS001	Computer Programming															
ACS101	Computer Programming Laboratory	✓	✓	✓	✓	✓					✓		✓	✓	✓	✓
AHS102	Computational Mathematics Laboratory	✓	✓			✓							✓	✓	✓	
Engineering Science Courses																
ACS001	Computer Programming	✓	✓	✓		✓					✓	✓	✓		✓	
ACS101	Computer Programming Laboratory	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓		✓
AME103	Computer Aided Engineering Drawing	✓		✓		✓	✓	✓		✓	✓		✓			✓
AEE001	Fundamentals of Electrical and Electronics Engineering	✓	✓											✓		

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
AEE101	Electrical and Electronics Engineering Laboratory	✓	✓			✓			✓	✓	✓		✓	✓		
ACS112	Engineering Practice Laboratory	✓	✓	✓	✓	✓	✓				✓			✓		✓
Humanities, Social Science including Management courses																
AHS001	English for Communication									✓						
AHS009	Environmental Studies	✓			✓			✓								
AHS101	Communication Skills Laboratory									✓	✓					
AHS015	Business Economics and Financial Analysis	✓	✓						✓	✓		✓				
AHS106	Research and Content Development	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Professional Core Courses																
ACS002	Data Structures	✓	✓	✓	✓	✓					✓		✓	✓		✓
ACS102	Data Structures Laboratory	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓
AIT001	Design and Analysis of Algorithms	✓	✓	✓	✓								✓	✓		✓
AEC020	Digital Logic Design	✓	✓	✓	✓						✓				✓	✓
ACS005	Database Management Systems	✓	✓	✓	✓						✓		✓	✓		✓

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
ACS004	Computer Organization and Architecture	✓	✓	✓	✓						✓		✓	✓	✓	
AIT101	Design and Analysis of Algorithms Laboratory	✓	✓	✓	✓								✓	✓		
ACS104	Database Management Systems Laboratory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AEC116	Digital Logic Design Laboratory	✓	✓	✓		✓				✓	✓				✓	
ACS003	Object Oriented Programming through JAVA	✓	✓	✓	✓						✓		✓	✓	✓	✓
ACS007	Operating Systems	✓	✓	✓	✓						✓		✓	✓	✓	✓
ACS008	Software Engineering	✓	✓	✓	✓	✓					✓		✓	✓	✓	✓
AIT002	Theory of Computation	✓	✓	✓	✓									✓		✓
AIT003	Computer Networks	✓	✓	✓	✓						✓		✓	✓		✓
ACS103	Object Oriented Programming through JAVA Laboratory	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
ACS106	Operating System Laboratory	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓
ACS107	Software Engineering Laboratory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
ACS006	Web Technologies	✓	✓	✓	✓	✓					✓		✓	✓	✓	✓

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
ACS009	Object Oriented Analysis and Design	✓	✓	✓	✓	✓				✓	✓		✓	✓		✓
AIT004	Compiler Design	✓	✓	✓		✓					✓			✓	✓	✓
ACS105	Web Technologies Laboratory	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	
AIT103	Case Tools Laboratory	✓	✓	✓		✓					✓		✓	✓	✓	✓
AEC023	Microprocessors Interfacing and Applications	✓	✓	✓							✓			✓		
AIT005	Linux Internals	✓			✓	✓							✓	✓	✓	✓
AIT006	Data Warehousing and Data Mining	✓	✓	✓	✓	✓			✓				✓	✓	✓	✓
AEC115	Microprocessors and Interfacing Laboratory	✓	✓	✓		✓			✓	✓	✓			✓		
AIT105	Linux Internals Laboratory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
AIT102	Data Warehousing and Data Mining Laboratory Cloud Computing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
AIT007	Cloud Computing	✓	✓	✓		✓					✓		✓	✓	✓	✓
AIT008	Software Testing Methodology	✓	✓	✓	✓	✓								✓	✓	✓
ACS012	Big Data and Business Analytics	✓	✓	✓		✓					✓		✓	✓	✓	✓
ACS110	Cloud Application Development Laboratory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
AIT104	Software Testing Methodology Laboratory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
ACS111	Big Data and Business Analytics Laboratory	✓	✓	✓		✓							✓	✓	✓	✓
ACS013	Information Security	✓	✓	✓	✓		✓		✓		✓		✓	✓	✓	✓
ACS014	Machine Learning	✓	✓	✓							✓			✓		✓
AIT302	Project Work (Phase - II)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Professional Elective Courses																
ACS501	C # and .NET framework	✓	✓			✓								✓	✓	✓
ACS502	Advanced Java Programming	✓	✓			✓								✓	✓	✓
ACS503	Advanced Computer Architecture	✓	✓											✓		✓
AIT501	Advanced Operating System	✓	✓											✓	✓	✓
AIT502	Parallel Programming Using CUDA	✓	✓											✓	✓	✓
ACS504	Multicore Architectures	✓	✓											✓		✓
ACS505	Database Security	✓	✓			✓								✓	✓	✓
ACS506	Cyber Security	✓	✓			✓								✓	✓	✓
ACS507	Network Programming and Management	✓	✓											✓	✓	
ACS508	Software Defined Networks	✓	✓											✓		
ACS509	High Speed Networks	✓	✓			✓								✓		

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
ACS510	Internet of Things (IoT)	✓	✓	✓	✓	✓		✓						✓		✓
ACS511	Image Processing	✓	✓			✓										✓
AIT503	Pattern Recognition	✓	✓			✓										✓
AIT504	User Interface Design	✓	✓			✓								✓		✓
AIT505	Advanced Databases	✓	✓	✓	✓	✓							✓	✓	✓	✓
AIT506	Parallel Computing	✓	✓											✓	✓	
AIT507	Distributed Databases	✓	✓											✓	✓	✓
AIT508	Software Development Methodology	✓	✓	✓		✓								✓	✓	✓
AIT509	Software Quality Management	✓	✓	✓		✓						✓		✓		✓
AIT510	Software Architecture and Design Patterns	✓	✓	✓		✓								✓		✓
AIT511	Software Engineering and Estimation	✓	✓	✓		✓								✓		✓
AIT512	Software Process and Project Management	✓	✓	✓		✓				✓	✓	✓		✓		✓
AIT513	Component Based Software Engineering	✓	✓			✓								✓		✓
ACS512	Artificial Intelligence	✓	✓			✓								✓		✓
ACS513	Soft Computing	✓	✓											✓		✓

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
ACS514	Elements of Neural Computation	✓	✓											✓		✓
ACS515	Computational Intelligence	✓	✓			✓								✓		✓
ACS516	Intelligent System Design	✓	✓											✓		✓
ACS517	Natural Language Processing	✓	✓			✓								✓		✓
ACS518	Cloud Infrastructure and Services	✓	✓			✓								✓		✓
ACS519	Wireless and Mobile Computing	✓	✓			✓								✓		✓
ACS520	High Performance Computing	✓	✓			✓								✓		✓
AIT514	E-commerce	✓	✓	✓	✓	✓					✓			✓	✓	
AIT515	Web Services	✓	✓			✓								✓		✓
AIT516	Green Computing	✓	✓											✓		✓
Open Elective																
AME511	Elements of Mechanical Engineering	✓	✓													
ACE511	Disaster Management	✓	✓				✓	✓								✓
ACE552	Geospatial Techniques	✓	✓				✓	✓								✓
ACS551	Principles of Operating System*	✓	✓			✓								✓	✓	✓
ACS552	JAVA Programming*	✓	✓	✓	✓	✓								✓	✓	✓
AEC551	Embedded System Design	✓	✓			✓								✓	✓	✓

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
AME552	Introduction to Automobile Engineering	✓	✓											✓	✓	✓
AME553	Introduction to Robotics	✓	✓			✓								✓	✓	✓
AAE551	Aerospace Propulsion and Combustion	✓	✓													✓
AEC552	Fundamentals of Image Processing	✓	✓			✓								✓	✓	
ACS553	Fundamentals of Database Management Systems∗	✓	✓			✓								✓	✓	✓
AIT551	Basics of Information Security and Cryptography∗	✓	✓			✓								✓	✓	✓
AHS551	Modeling and Simulation	✓	✓			✓										
AHS552	Research Methodologies	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AEE551	Energy from Waste	✓		✓			✓	✓					✓			
AAE552	Finite Element Analysis	✓	✓													
AME334	Basic Refrigeration and Air-Conditioning	✓	✓													
AAE553	Launch Vehicles and Controls	✓	✓			✓										

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 in table.

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 re-medial measures will be taken up such that the student gets benefited before going for end exams. The positive and negative comments made by the students about the course are recorded and submitted to the departmental academic council (DAC) 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 DAC 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 DAC'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	25	Answer script
		Alternative Assessment Tools (AAT)	Twice in a semester	5	Video / Quiz / assignment
		Semester End Examination	Once in a semester	70	Answer script
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

S No	Courses	Components	Frequency	Max. Marks	Evidence
		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 assessthe 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.

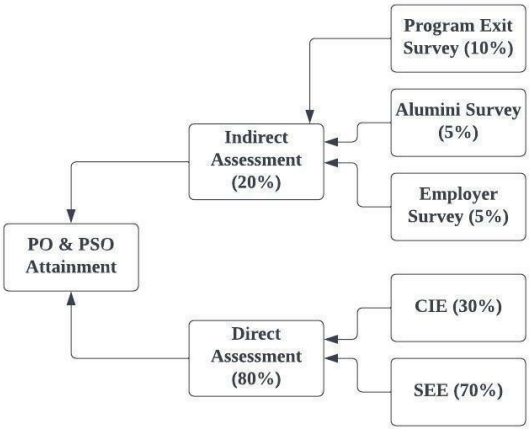


FIGURE 4: Evaluation process of POs/PSOs attainment

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 – A 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

15.2 sample Course Description:

COURSE DESCRIPTION

Department	INFORMATION TECHNOLOGY				
Course Title	DESIGN AND ANALYSIS OF ALGORITHMS				
Course Code	AIT001				
Program	B.Tech				
Semester	III				
Course Type	Core				
Regulation	R-16				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	-	3	3	2
Course Coordinator	Dr. B.V. Rao, Professor, IT				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	ACS001	I	Computer Programming
B.Tech	ACS002	II	Data Structures

II COURSE OVERVIEW:

The primary objective of this course is to introduce the concept of algorithm as a precise mathematical concept, and study how to design algorithms, establish their correctness, study their efficiency and memory needs. The course consists of a strong mathematical component in addition to the design of various algorithms.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Design And Analysis Of Algorithms	70 Marks	30 Marks	100

IV CONTENT DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	Power Point Presentations	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Open Ended Experiments	✓	Seminars	✓	Quiz	x	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). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIE examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into FIVE modules and each 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
70%	Understand
10%	Remember
20%	Apply
0%	Analyze
0%	Evaluate
0%	Create

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks, with 25 marks for Continuous Internal Examination (CIE) and 05 marks for Quiz.

Component	Theory		Total Marks
Type of Assessment	CIE Exam	Quiz	
CIA Marks	20	10	30

Continuous Internal Examination (CIE):

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

Quiz - Online Examination

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

VI COURSE OBJECTIVES:

The students will try to learn:

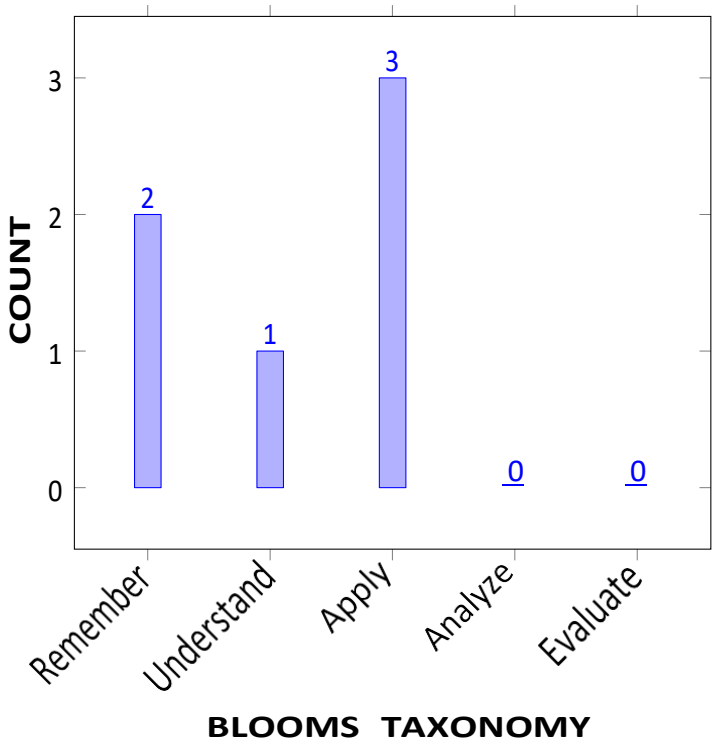
I	Calculate performance of algorithms with respect to time and space complexity.
II	Illustrate the graph traversals and tree traversals to solve the problems
III	Demonstrate the concepts greedy method and dynamic programming for several applications like knapsack problem, job sequencing with deadlines, and optimal binary search tree, TSP.
IV	Illustrating the methods of backtracking and branch bound techniques to solve the problems like n-queens problem, graph colouring and TSP respectively

VII COURSE OUTCOMES:

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

CO 1	**Find** the (worst case, randomized, amortized) running time and space complexity of given algorithms using techniques such as recurrences and properties of probability.	Remember
CO 2	**Apply** divide and conquer algorithms for solving sorting, searching and matrix multiplication.	Apply
CO 3	**Make Use of** appropriate tree traversal techniques for finding shortest path.	Apply
CO 4	**Identify** suitable problem solving techniques for a given problem and finding optimized solutions using Greedy and Dynamic Programming techniques	Remember
CO 5	**Utilize** backtracking and branch and bound techniques to deal with traceable and in-traceable problems.	Apply
CO 6	**Describe** the classes P, NP, NP-Hard, NP-complete for solving deterministic and non deterministic problems.	Understand

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.
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	AAT
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	1	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.	1	CIE/SEE/AAT
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.	1	AAT

3 = High; 2 = Medium; 1 = Low

X HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

PROGRAM SPECIFIC OUTCOMES		Strength	Proficiency Assessed by
PSO 1	Design next-generation computer systems, networking devices, search engines, soft computing and intelligent systems, web browsers, and knowledge discovery tools	2	SEE/AAT

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	Analyze the running time and space complexity of given algorithms using techniques such as recurrences, potential functions, properties of probability by applying the **mathematical principles, engineering principles and scientific principles**	3
	PSO1	Understand the basic properties of asymptotic notations, probability analysis for designing **algorithms, system software and Networking.**	3
CO 2	PO 1	Apply divide and conquer algorithms for solving sorting, searching and matrix multiplication problems to integrate **mathematical principles, engineering Principles,** and **Scientific Principles.**	3
	PO 2	Understand the given **problem** and **develop the solution** for solving sorting, searching and matrix multiplication problems **complex engineering problems** and **Interpretation of results.**	4
	PSO1	Build divide and conquer algorithms for solving sorting, searching, **Big data** analysis and matrix multiplication problems through **system software.**	2
CO 3	PO 1	Utilize appropriate tree traversal techniques for solving graph problems to integrate **mathematical principles, scientific Methodology, and engineering principles.**	3
	PO 2	Understand the given **problem** traversal techniques to **develop the solution** for graph problems **complex engineering problems and interpretation of results.**	4

Course Outcomes	PO'S PSO'S	Justification for mapping (Students will be able to)	No. of Key competencies matched.
CO 4	PO 1	Choose (Pick) greedy algorithms for finding solutions of minimization and maximization problems to support study of their own **engineering discipline and methodologies.**	2
	PO 2	Understand the given **problem** and **develop the solution** using greedy methods in reaching substantiated conclusions from the provided **problem identification, information, interpret of results, complex engineering problems** and **Experimental design.**	7
	PO 3	Select appropriate technique from the greedy techniques for given problem and **apply** chosen method for finding the solutions of given problem **define problem, Evaluate outcomes, innovative solutions, engineering activities** and**engineering processes**	7
	PO 12	make use of greedy and dynamic programming techniques for **beginning works on advances degree, current trends in computer science, efforts for personal continue education** ,personal development and **on going learning.**	4
CO 5	PO 1	Identify backtracking and branch and bound techniques to compact with traceable and in -traceable problems by applying the knowledge of **mathematics, Engineering fundamentals** and to find the solution of **complex engineering problems.**	3
	PO 4	Understand the given set of problems from the **provided information, to identify, classify** and describe the **performance of systems** approach and textbfengineering problems and principles.	6
	PO 12	Utilize branch and bound techniques to learn for solving problems in**current trends of computer science, on going learning, continuum education,** beginning works for **advance degree** and personal development.	4
CO 6	PO 1	Understanding the concepts of classes P, NP, NP-Hard, NP- complete for solving deterministic and non-deterministic problems in attainment of mathematical **principles, engineering methodologies and scientific principles.**	3

Course Outcomes	PO'S PSO'S	Justification for mapping (Students will be able to)	No. of Key competencies matched.
	PO 4	Identify the given complex problem and choose the deterministic algorithms for solving the given decision problems from the **provided information** in accomplishment of **engineering problems, performance of systems, to identify , classify and principles.**	6
	PO 12	Describe P,NP,NP-Hard, NP-complete for solving deterministic and non deterministic problems which are useful for **personal development**, on going learning ,**continuum education** and **current trends in computer science.**	3
	PSO 1	Understand the basic properties of deterministic algorithms in the areas related to **computer programs, Big data, Machine Learning and Networking.**	3

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	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-
CO 2	3	4	-	-	-	-	-	-	-	-	-	-	2	-	-
CO 3	3	4	-	-	-	-	-	-	-	-	-	-	-	-	-
CO 4	2	7	7	-		-	-	-	-	-	-	4	-	-	-
CO 5	3	-	-	6	-	-	-	-	-	-	-	4	-	-	-
CO 6	3	-	-	6	-	-	-	-	-	-	-	3	3	-	-

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	100	-	-	-	-	-	-	-	-	-	-		50.0	-	-
CO 2	100	40	-	-	-	-	-	-	-	-	-	-	33.33	-	-
CO 3	100	40	-	-	-	-	-	-	-	-	-	-	-	-	-
CO 4	100	70	70	-		-	-	-	-	-	-	50.0	100	100	-
CO 5	100	-	-	54.54	-	-	-	-	-	-	-	50.0	-	-	-
CO 6	100	-	-	54.54	-	-	-	-	-	-	-	37.5	50.0	-	-

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 ≤ C ≤ 5% – No correlation
1 -5 <C≤ 40% – Low/ Slight
2 - 40 % <C < 60% –Moderate
3 - 60% ≤ 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	-	-	-	-	-	-	-	-	-	-	1	-	-
CO 3	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO 4	3	3	3	-	-	-	-	-	-	-	-	2	-	-	-
CO 5	3	-	-	2	-	-	-	-	-	-	-	2	-	-	-
CO 6	3	-	-	2	-	-	-	-	-	-	-	1	2	-	-
TOTAL	18	7	3	4	-	-	-	-	-	-	-	5	5	-	-
AVERAGE	3.0	2.3	1.0	1.0	-	-	-	-	-	-	-	1.7	1.7	-	-

XVI ASSESSMENT METHODOLOGY-DIRECT:

CIE Exams	PO 1, PO 2, PO 3,PO 4	SEE Exams	PO 1, PO 2, PO 3,PO 4	Seminars	PO 2
Laboratory Practices	-	Student Viva	-	Certification	-
Term Paper	-	5 Minutes Video	PO 4	Open Ended Experiments	-
Assignments	PO1				

XVII ASSESSMENT METHODOLOGY-INDIRECT:

x	Assessment of mini projects by experts	✓	End Semester OBE Feedback

XVIII SYLLABUS:

MODULE I	**INTRODUCTION**
	Algorithm: Pseudo code for expressing algorithms; Performance analysis: Space complexity, time complexity; Asymptotic notations: Big O notation, omega notation, theta notation and little o notation, amortized complexity; Divide and Conquer: General method, binary search, quick sort, merge sort, Strassen's matrix multiplication.
MODULE II	**SEARCHING AND TRAVERSAL TECHNIQUES**
	Disjoint set operations, union and find algorithms; Efficient non recursive binary tree traversal algorithms, spanning trees; Graph traversals: Breadth first search, depth first search, connected components, bi-connected components.
MODULE III	**GREEDY METHOD AND DYNAMIC PROGRAMMING**
	Greedy method: The general method, job sequencing with deadlines, knapsack problem, minimum cost spanning trees, single source shortest paths. Dynamic programming: The general method, matrix chain multiplication optimal binary search trees, 0/1 knapsack problem, single source shortest paths, all pairs shortest paths problem, the travelling salesperson problem.
MODULE IV	**BACKTRACKING AND BRANCH AND BOUND**
	Backtracking: The general method, the 8 queens problem, sum of subsets problem, graph coloring, Hamiltonian cycles; Branch and bound: The general method, 0/1 knapsack problem, least cost branch and bound solution, first in first out branch and bound solution, travelling salesperson problem.
MODULE V	**NP-HARD AND NP-COMPLETE PROBLEM**
	Basic concepts: Non-deterministic algorithms, the classes NP - Hard and NP, NP Hard problems, clique decision problem, chromatic number decision problem, Cook's theorem.

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2. http://openclassroom.stanford.edu/MainFolder/CoursePage.php?course=IntroToAlgorithms
3. http://www.facweb.iitkgp.ernet.in/sourav/daa.html

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 T1: 4.1
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO - PO Mapping	-	
CONTENT DELIVERY (THEORY)			
2	Introduction: Algorithm, Pseudo code for expressing algorithms, Performance Analysis- Space complexity, Time complexity.	CO 1	T1:1.1-1.3.2
3	Asymptotic Notation-Big oh notation, Omega notation, Theta notation and Little oh notation	CO 1	T1:1.3.3
4	Amortized complexity.	CO 1	T2:2.3
5	Divide and conquer: General method.	CO 2	T1:3.1
6	Divide and conquer: Binary search, Quick sort	CO 2	T1:3.2-3.5
7	Divide and conquer: Merge sort, Strassen'smatrix multiplication.	CO 2	T1:3.4-3.7
8	Disjoint set operations.,	CO 3	T1:2.5
9	Union and find algorithms.	CO 1	T1:2.5.2
10	Non-recursive binary tree traversal algorithms,	CO 3	T1:6.1
11	Spanning tree.	CO 3	T1:6.3
12	Graph traversals: Breadth first search.	CO 3	T1:6.2.1
13	Graph traversals:Depth first search.	CO 3	T1:62.2
14	Connected components, Bi-connected components.	CO 3	T1:6.3-6.4
15	Greedy general method.	CO 4	T1:4.1
16	Greedy method: Job sequencing with deadlines.	CO 4	T1:4.4
17	Greedy method: 0/1 knapsack problem, Minimum cost spanning trees.	CO 4	T1:4.2-4.5
18	Greedy method: Single source shortest path problem	CO 4	T1:4.8
19	Dynamic Programming: General method.	CO 4	T1:5.1
20	Dynamic Programming: Matrix chain multiplication.	CO 4	T1:5.2
21	aDynamic Programming: Optimal binary search trees.	CO 4	T1:5.5
22	Dynamic Programming:0/1 knapsack problem.	CO 4	T1:5.7
23	Dynamic Programming:All pairs shortest path problem.	CO 4	T1:5.5
24	Dynamic Programming: Single source shortest path problem.	CO 4	T1:5.4
25	Dynamic Programming: Travelling sales person problem.	CO 4	T1:5.9
26	Backtracking: General method.	CO 5	T1:7.1
27	Backtracking: 8-queens problem.	CO 5	T1:7.2

28	Backtracking: Sum of subsets problem.,	CO 5	T1:7.3
29	Backtracking: Graph coloring	CO 5	T1:7.4
30	Backtracking :Hamiltonian cycles	CO 5	T1:7.5
31	Branch and Bound: General method.	CO 5	T1:8.1
32	Branch and Bound :0/1 knapsack problem	CO 5	T1:8.2
33	Branch and Bound: Least Cost Branch and Bound.	CO 5	T1:8.2.1
34	Branch and Bound: FIFO Branch and Bound.	CO 5	T1:8.2.2
35	Branch and Bound :Travelling sales person problem	CO 5	T1:8.3
36	NP-Hard and NP-Complete problems: Basic concepts.	CO 6	T1:11.1
37	Non-deterministic algorithms.	CO 6	T1:11.1.1
38	The classes NP -Hard and NP, NP Hard	CO 6	T1:11.1.2
39	Clique decision problem	CO 6	T1:11.3.1
40	Chromatic number decision problem.	CO 6	T1:11.3.3
41	Cook's theorem.	CO 6	T1:11.2
PROBLEM SOLVING/ CASE STUDIES			
42	Write a program to implement quick sort.	CO 2	T1:3.5
43	Write a program to implement Merge sort	CO 2	T1:3.4
44	Write a program to implement Warshall's algorithm	CO 3	t1:3.5.5
45	Write a program to implement Knapsack Problem	CO 4	T1:4.2
46	Write a program to implement Graph Traversals	CO 4	T1:6.2
47	Write a program to implement Shortest Paths Algorithm	CO 4	T1:5.3
47	Write a program to implement Minimum Cost Spanning Tree	CO 4	T1:4.5
48	Write a program to implement Tree Travesrsals	CO 4	T1:6.1
49	Write a program to implement Sum Of Sub Sets Problem	CO 5	T1:7.3
50	Write a program to implement Travelling Sales Person Problem	CO 5	T1:5.9
51	Write a program to implement Minimum Cost Spanning Tree	CO 5	T1:4.5
52	Write a program to implement All Pairs Shortest Paths	CO 5	T1:5.3
53	Write a program to implement N Queens Problem	CO 5	T1:7.2
DISCUSSION OF DEFINITION AND TERMINOLOGY			
54	Discuss definitions and terminology on introduction to algorithms, divide and conquer.	CO 1,2	T1:3.0
55	Discuss definitions and terminology on greedy method.	CO 1,2, 3	T:4.0
56	Discuss definitions and terminology on dynamic programming.	CO 4	T:5.0
57	Discuss definitions and terminology on bracktracking, branch and bound.	CO 5	T1:7-8
58	Discuss definitions and terminology on NP-Hard and NP-Complete.	CO 6	T1:11.0
DISCUSSION OF QUESTION BANK			
59	Discuss questions on introduction to algorithms, divide and conquer.	CO 1,2	T1:3.0
60	Discuss questions on greedy algorithm, dynamic programming.	CO 4	T1:3,4

61	Discuss questions on bracktracking, branch and bound and NP-hard and NP-Complete.	CO 5,6	T1:7,8,11

Signature of Course Coordinator **HOD,IT**